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Personal-Metabolism (PM) coupled with Life Cycle Assessment (LCA) Model: Danish Case Study

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Abstract:

Sustainable and informed resource consumption is the key to make everyday living sustainable for entire populations. An intelligent and strategic way of addressing the challenges related with sustainable development of the everyday living of consumers is to identify consumption-determined hotspots in terms of environmental and health burdens, as well as resource consumptions. Analyzing consumer life styles in terms of consumption patterns in order to identify hotspots is hence the focus of this study. This is achieved by taking into account the entire value chain of the commodities consumed in the context of environmental and human health burdens, as well as resource consumptions. A systematic commodity consumption, commodity disposal, and life style survey of 1281 persons living in urbanized Danish areas was conducted. The findings of the survey showed new impact dimensions in terms of Personal Metabolism (PM) patterns of residents living in urbanized areas of Denmark. Extending the PM analysis with Life Cycle Assessment (LCA) provided a clear picture of the per capita environmental and human health burdens, as well as resource consumptions, and the exact origin hereof.

A generic PM-LCA Model for all the 1281 persons was set-up in Gabi 6. The assessment results obtained applying the model on all 1281 personal consumption scenarios yielded the 1281 Personal Impact Profiles (PIPs). Consumption of food and energy (electricity and thermal energy) proved to be the primary impact sources of PM, followed by transport. The PIPs further revealed that behavioral factors (*e.g.* different diets, use of cars, household size) affect the profiles. Hence, behavioral changes are one means out of many that humanity will most likely have to rely on during the sustainable development process. The results of this study will help the Danish and other comparable populations to identify and prioritize the steps towards reducing their environmental, human health, and resource consumption burdens.

Key words: Personal metabolism; Sustainable consumption; Resource consumption; Life cycle assessment; Sustainability assessment, Sustainable development

1. Introduction

Persistent population growth and urbanization have led to an increased demand for man-made resources. This inevitably puts tremendous pressure on the global environment and natural resources. In particular, the increasing natural and man-made resource consumption rates and associated emissions are becoming more and more problematic. In the period 1900 to 2005, the extraction of construction materials grew by a factor of 34, ores and minerals by a factor of 27, fossil fuels by a factor of 12, and biomass by a factor of 3.6 (UNEP, 2011). The convenient and modern life styles prevailing in high population density urban areas are, just as rural life styles, both directly and indirectly associated with environmental, human health impacts. However, urban life styles compared to rural life styles lead to an increased consumption of both natural and man-made resources. In other words, not only is the increasing population adding to environmental and human health burdens, as well as resource consumptions related with human activities, but also the increasing urbanization (Parikh *et al.*, 1991). Due to the complexity of the supply-chains, humans tend not to clearly perceive and realize the impacts entailed with specific life styles. This further makes it more difficult to relate to the environmental and human health impacts induced at a global level.

Private consumption plays an important role in relation to the impacts posed by various life styles. EEA (2010) reveals that private consumption expenditures grew by 35% in the EU-27 Member States between 1990 and 2007 with the greatest growth in the EU-12 Member States (75%). The complexity of the consumption increase in terms of increased consumption of specific goods is illustrated by the same report (EEA, 2010). For example, meat imports to the EU-15 increased by 120% from 1990-2007, cereal imports increased by 83%, frozen vegetables by 174%, and bananas by 92% over the same period. This suggests that specific goods follow specific consumption patterns. One of the factors contributing to the overall increased consumption is the growing tendency of households to become smaller in terms of persons per household. This decrease in household size inevitably cause more energy and water use along with increased waste generation per person, due to the general decrease in consumption benefits of economies of scale (EEA, 2005). The increasing urbanization, growing consumption, and decrease in household size are factors that need to be analyzed in the context of environmental and human health burdens, as well as resource consumptions, in order to quantify the various impacts of urban systems and residents.

The path towards quantification of the environmental, human health, and resource burdens of urban residents requires a holistic approach accounting for the impacts across the life cycle of the products covering all the upstream and downstream resource use and material interventions. The Personal Metabolism (PM) notation used here is simply a synonym used when a study focuses on individual/resident consumption, rather than city/system scale consumption, such as quantified in Urban Metabolism (UM). PM refers to estimation of annual consumption patterns (also called metabolic flows) of the individuals residing in particular localities. PM provides a holistic framework for analyzing the environmental burden of urban residents. Material Flow Accounting (MFA) and non-mass based methods (*i.e.* emergy, exergy concepts *etc.*) of analysis are considered conventional methods applied for quantification of resource and environmental burdens (Pincetl *et al.*, 2012). MFA studies take into account only direct mass and energy exchanges and hence ignore the embedded upstream and downstream processes required to provide a unit of resources consumed by the urban resident (Goldstein *et al.*, 2013). Raw material equivalents (RME) based on economy-wide material flow accounts (EW-MFA) and Input output tables attempt to account for upstream raw material consumption in MFA (Barles, 2009; Eurostat, 2015). Emergy (embodied energy) assessment methods attempt to take a more comprehensive approach than MFA by further taking into account embodied energy of the metabolic flows across city system boundaries (Liu *et al.*, 2011). Limitations have been identified in these approaches, invalidating the application of such methods for sustainability assessment of cities/city systems (Pincetl *et al.*, 2012). The present state of art of sustainability assessment of large-scale systems, such as urban systems, suggests that it is essential to couple system consumption and emissions with holistic environmental assessment methods, such as UM studies coupled with Life Cycle Assessment (LCA). LCA is a well-established methodology for quantifying environmental burdens of common products, technologies and services (Finnveden *et al.*, 2009; Guinée *et al.*, 2011; Pennington *et al.*, 2004; Rebitzer *et al.*, 2004). Coupling of well-established and/or standardized methods allows for accounting of up- and down-stream impacts of associated with the urban system being assessed and hence provides an expanded environmental burden estimate beyond direct mass and energy accounting (Goldstein *et al.*, 2013; Ulgiati *et al.*, 2011). PM coupled with the LCA (PM-LCA) approach accounts for upstream as well as downstream resource use and impacts. Hence, for the purposes of the present study, PM-LCA is considered the best-suited approach for assessing environmental impacts of urban residents. Basically, PM-LCA is a special LCA defined as consumer/lifestyle LCA (Hellweg and Milà i Canals, 2014).

In past studies attempting to establish resource consumption patterns in urban areas a variety of approaches have been applied. Gilg and Barr (2006) studied the water consumption patterns by sampling 1600 households from Devon, England. Cluster analysis of the data from the 1600 households was used to identify groups with varying commitment towards the environment. The study concludes that, if policies aimed at water and energy conservation take into account behavioral complexity, behavioral groupings, and lifestyle types, then there is greater chance of success in implementation of these policies. Lahteenoja *et al.* (2007) carried out a detailed resource consumption study on 30 Finish households by accounting for material inputs to accommodation, food and beverage, transport, leisure time activities, tourism, household goods, and electronic appliances. The study estimated the Material Input Per Service unit (MIPS) for the typical Finish household. Baiocchi *et al.* (2010) analyzed consumer data on lifestyles in the United Kingdom (UK) using an Input-Output model to estimate Carbon Dioxide (CO_2) emissions. In total, 56 UK lifestyles were analyzed. The UK study reveals the importance of considering the effects of lifestyles in relation to determining CO_2 emissions. Newton & Meyer (2012) present a comprehensive urban resource consumption study of 1250 households in Melbourne, Australia. The Melbourne study seeks to assess how much of the resource consumption is attributed to cities and accommodation and how much is directly associated with the individual behavior of the consumer. Five parameters (water, energy, domestic appliances, travel, and accommodation space) were considered in the study. Newton & Meyer (2012) conclude that urban resource consumption is affected more by contextual and locational factors (household, dwelling, and location) than individual (structural and attitudinal) factors.

Schmidt and Muños (2014) report the hybrid Input Output (IO) study on Danish production and consumption. The study applies the FORWAST model (Schmidt *et al.*, 2010) covering Danish production and consumption across 145 product groups (physical products, service products, waste treatment services and household uses). Additionally the FORWAST model takes into account emissions associated with imports and exports of products, direct land use change, and radiative forcing from aviation. Druckman and Jackson, (2009) applied a socio-economically disaggregated quasi-multi-regional IO model to estimate the carbon footprint of UK households. The study included CO_2 embedded in goods and services purchased by UK households; CO_2 emissions caused by fuel use by the households; CO_2 emissions due to personal vehicle use, and; CO_2 emissions related with personal air transport.

Most of the above studies apply an IO approach and only cover a fraction of the consumption related metabolic flows across urban residential areas. In addition, the majority of these studies only report the carbon footprint of urban resource consumption. There is no study which addresses a wider range of environmental impact categories.

This is the first study of its kind focusing on estimation of Personal Impact Profiles (PIPs) by applying the PM-LCA approach to analyze resource consumption and waste disposal patterns of 1281 persons in urban areas of Denmark, as well as the associated environmental impacts. The study is part of a larger work on environmentally sustainable wellbeing from the Psychological Institute at Aarhus University named "Values, Ecologically Sustainable Behavior and Individual Wellbeing. This paper reports solely on the environmental impacts of resource consumption and waste disposal patterns on the individual level.

2. Methodology

The work comprises several steps starting from designing and distributing a comprehensive questionnaire for estimation of metabolic flows. Figure 1 illustrates the methodology adopted. From the metabolic flows quantified via the questionnaires, the PM-LCA approach was subsequently used to estimate the impacts related with the metabolic flow. The PM-LCA is the only assessment approach, which takes into account the related upstream and downstream impacts of the individual consumption. The functional unit chosen for the study corresponds to one person equivalent per year (p.e.-year), which represents the consumption of resources by one individual during a period of one year. All direct and indirect consumptions were modelled and are hence within the system boundaries of the LCA. The following sub-sections describe in detail the methodology for each of the steps of the work.

2.1. Collecting data on Personal Metabolism (PM)

A questionnaire was articulated comprising 45 questions specifically related to demography, accommodation, energy (electricity and thermal energy) consumption, transportation (private and public transportation as well as air travel), food consumption, and non-food products and services. A sample questionnaire of the 45 questions relating to metabolic flows is presented in the Supplementary Information (SI) I.

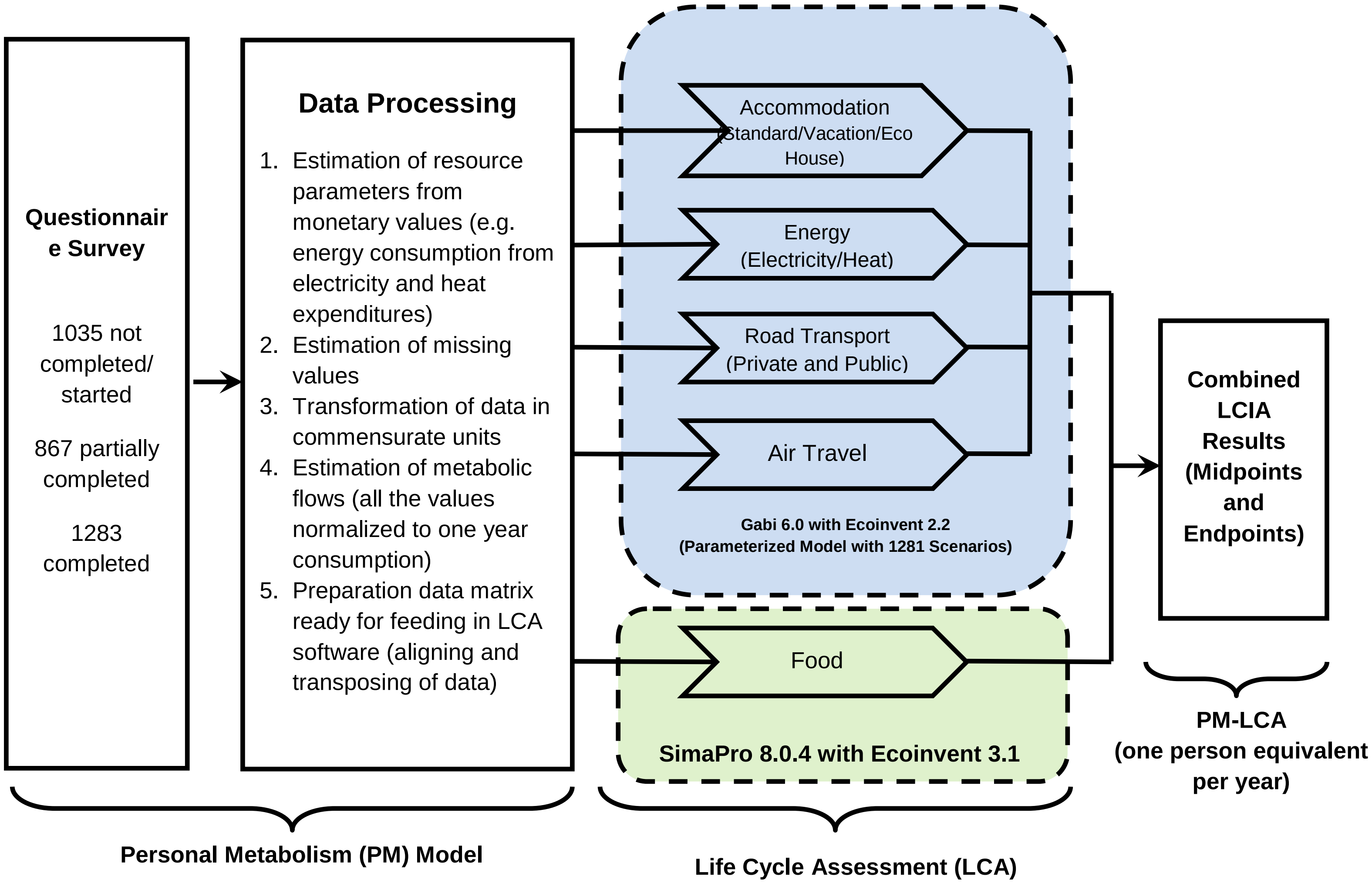

Figure 1: Methodology followed for estimating environmental impacts of urban residents for one year using Personal Metabolism (PM) coupled with Life Cycle Assessment (LCA) approach (refer to SI II for further details on data processing)

As can be seen from the questionnaire sample, a personal expenditure and actual consumption disaggregation methodology was adopted (*e.g.* expenditure for products and services, such as electricity, thermal energy, and personal products, and actual consumption of food products we compiled via the questionnaire). The basic approach taken in the questionnaire was not to ask for exact values of the consumption, as this was deemed too difficult/tedious for respondents to provide. Instead, respondents were asked to choose from a range of interval values (*e.g.* 500-1000) for each consumption item. This approach worked well. Of the 3185 persons clicking on the link to the questionnaire, 1283 completed and 867 partially completed the questionnaire. Of the 1283 respondents, two respondents were found to be living in a large single community comprising 140 people with partly shared income, partly shared living and outdoors area, partly shared food production, etc. Hence these two respondents were removed from the data set, to form a final dataset of 1281 respondents. The survey was carried out mainly in urban areas of Denmark, foremost Albertslund, Ry, Glostrup, Copenhagen, and Aarhus. A detailed overview of how data were collected is provided in section 2 of the SI II.

2.2. Data processing to estimate yearly metabolic flows

The present study attempts to capture all the important components of resource consumption of urban residents. The data collected was subsequently processed in Microsoft Excel® in order to estimate yearly metabolic flows. These processing steps included converting the above mentioned interval values in the questionnaire (*e.g.* 500-1000) to interval mid-points (*e.g.* 750). The processing also included compensating for missing data points in uncompleted questions in the questionnaire sections relating to accommodation, electricity, and thermal energy. Compensating for missing values was conducted using arithmetic mean values from the completed questionnaires. A detailed account of how data were processed is given in section 4 in the SI II.

The metabolic flows for each household were estimated from further data processing using various approaches, including conversion of monetary values to consumption values (*e.g.* from electricity expenses to MJ consumption per year), conversion of expenditure on transportation to distance travelled (person km per year), conversion of daily and weekly intake of food to yearly intake. Each of these processing steps is described in detail in the following sub-sections.

2.3. Estimation of Impacts using LCA

A generic parameterized LCA model was set-up in Gabi 6.0 to estimate impact potentials from accommodation, energy use, road transport, and air travel. The Gabi 6.0 model was constructed and 1281 scenarios were created in such a manner that the data of all the 1281 persons could be processed efficiently. However, as Gabi 6.0 comes with the Ecoinvent 2.2 database which does not have food related processes such as milk, butter, cheese, vegetables, beef, pork, meat, *etc.*, SimaPro 8.0.4 with the Ecoinvent 3.1 database was used in addition to separately model food processes (refer to Figure 1). For the impact assessment the ReCiPe 2008 (Goedkoop *et al.*, 2009) Life Cycle Impact Assessment (LCIA) method (hierarchical perspective) was used for impact potential quantification. ReCiPe 2008 was chosen as the LCIA method, as this method provides midpoint and endpoint indicators as well as single scores. As earlier mentioned, in the other parts of the large scale study we have undertaken, we plan to use all these three level (midpoint, endpoint and single score) indicators for various purposes, such as to see the effect of behavioral factors on environmental impacts, cluster analysis, and correlation analysis. The results obtained from Gabi 6.0 and Simapro 8.0.4 were further processed in Microsoft Excel to compute the aggregated impact of the personal metabolism of the Danish urban resident.

2.3.1. Accommodation

Accommodation includes impacts related to the construction, maintenance, and renovation of buildings intended for accommodation. The end-of-life phase has not been considered in this work due to a lack of appropriate data on the processing and eventual exact fate of waste streams of construction wastes. Thermal energy and electricity consumption are dealt with separately below.

In the questionnaire, respondents were asked to provide information on: 1) the number of adult and child residents in their respective households; 2) the year they moved into their current home; 3) their expenditure on renovations, and; 4) the address of their primary home and their vacation house/secondary home, if they owned one. Addresses were asked for, as we deemed it likely that many respondents would not be able to provide exact information on, for example, the exact size of their home. Using the address provided, the exact accommodation data of each respondent was then looked up in the Danish Construction and Accommodation Register which provides a rich source of information on each home in Denmark, including information on the size of the home (in square meters), the type of home (*e.g.* house, apartment *etc.*), and year of construction. This information was then added to the dataset for each respondent. While this data processing step constituted a very time consuming part of the data processing it also provided a way of gaining objective data on each respondent's primary and secondary home.

Next, the Accommodation area per person was estimated by dividing the size of the primary (and secondary) home by the total number of residents. Based on data provided by the Danish Building Institute a standard house was considered to have an area of 145 m^2 and a service life of 60 years in accordance with the German Sustainable Building Council (DGNB) certification scheme. A detailed inventory of materials required for constructing a standard house was generated and is presented in SBI (2015). The Ecoinvent 2.2 database was used to build a Gabi 6.0 model for a standard house (refer to Table S1 in SI III for a list of LCI processes used). Since a considerable fraction of respondees, in line with the rest of the Danish population, owned a vacation house, vacation houses had to be included in the modelling of the accommodation consumption patterns. An additional fraction of the respondents lived in so-called eco-houses. In order to model vacation and eco-houses it was assumed that a vacation house has 50% and an eco-house has 25% of the impacts of a standard house, due to limited data availability on impact profiles on vacations house and eco-houses. This assumption was based on the Carbon Footprint (CFP) estimate for a state-of-the-art eco-house made of recycled materials, such as obsolete steel from a shipping container (Andersen, 2012).

As new materials will be procured and used for maintaining and renovating buildings used for accommodation, these expenditures have also been accounted for. The standard construction cost of 13608 DKK/m^2 was used to convert the expenditure on maintenance and renovations to an equivalent of constructing a standard house area (Dol and Haffner, 2010). This equivalent area was then divided by the number of residents and added to the standard house area per person used to finally estimate the total environmental impacts of accommodation.

2.3.2. Energy Consumption

Urban residents use electricity and thermal energy to satisfy their energy needs. In the questionnaire, respondents were asked to provide the household's yearly expenditures for electricity and thermal energy, respectively, as it was deemed unlikely that they would be able to provide the answer in more direct consumption values (*i.e.* kilowatt-hours or mega joule). Since electricity prices in Denmark vary little across suppliers, an average conversion rate was used to convert yearly electricity expenditures into yearly consumptions in mega joule.

For thermal energy, however, data processing was considerably more complicated. First, while the respondents in the sample use different thermal energy sources, *viz.*; district heating (80.83%), natural gas (5.22%), heating oil (4.05%), wood (5.07%), and electricity (4.83%), it was only possible to account for district heating in the analysis of environmental impacts. Moreover, various thermal energy sources do not have the same price/efficiency ratio. Consequently, it was necessary to account for the amount of energy (in mega joules) that can be purchased per Danish Krone for each thermal energy source. Data on the thermal energy source used by each respondent was collected from the Danish Construction and Accommodation Register, whereas conversion rates from the Danish Energy Regulatory Authority (DERA) was used in converting yearly expenses into consumptions in mega joules for each respondent. For respondents with non-district heating it was then assumed that the amount of mega joules purchased was equivalent to the amount of mega joules it would have been necessary to provide using district heating.

Second, since district heating plants in Denmark produce heat in different ways and display different efficiency rates, local prices for district heating vary considerably (more than a 100%). Moreover, prices are also determined (to a lesser extent) by the type of accommodation (*i.e.* house or apartment). To account for local price variations in thermal energy supply for houses and apartments, respectively, the district heating price statistics provided by DERA were used. These include estimates of the yearly expenditures for heating a standard house and standard apartment. Based on these estimates the average price per mega joule for houses and apartments, respectively, was calculated for each heating plant in Denmark. Next, zip codes were used to ascribe each respondent to one or more heating plant(s). Please refer to SI II for an elaborated account of how the analysis was conducted.

Having converted yearly household expenditures for electricity and thermal energy into yearly consumptions, the per person expenditure was then estimated by dividing yearly consumptions with the number of residents in the household.

Missing values for thermal energy provision and electricity were filled using the arithmetic mean values from filled out questionnaires. The arithmetic mean of expenditure per person per square meter was calculated. Then missing values were estimated by multiplying the area of the home by the mean expenditure per person per square meter. The appropriate processes from the Ecoinvent 2.2 database were used to model impacts of electricity and thermal energy use in Gabi 6.0 (please refer to Table S1 in SI III for a list of LCI processes used).

2.3.3. Road Transportation

Transportation is an essential part of day-to-day life. In this study, all types of transportation (*i.e.* public trains, buses and private road transport, as well as air travel) have been considered to estimate environmental impacts associated with person transport.

In the questionnaire, respondents were asked to provide the registration number for their primary motorized vehicle. The registration number was then looked up in the Danish Register of Motor Vehicles which provides a detailed source of information for each registered vehicle in Denmark. This includes information on the year of production and the type of vehicle (diesel, gasoline or electric). Respondents were also given the opportunity to provide this information themselves, if they could not remember the vehicle registration number. In cases where information on the type of vehicle had not been provided by the respondent, the vehicle was assumed to be a gasoline powered car (which is the most common type of privately owned motorized vehicle in Denmark, refer to Table S6.5 in SI 2).

Respondents were also asked to indicate the year of purchase of the vehicle, as well as the total number of kilometers travelled in the primary vehicle in one year. Using the data about the production year of vehicle, the road distance travelled was divided for respective Euro Emissions Standards to enable an estimation using appropriate Ecoinvent 2.2 passenger car processes. Further, electric cars were modelled using unit processes for electrical cars.

Respondents were also asked for their expenditure on public transportation, in order to estimate the kilometers travelled by means of public transportation. Based on estimates from Statistics Denmark (2015) on the total number of kilometers travelled by train and bus, respectively, it was assumed that 52% of the total kilometers travelled by each respondent was by train and 48% by bus. Please refer to SI II for further information on how the analysis was conducted. Once the public transportation distances were calculated, the impacts were computed using appropriate Ecoinvent 2.2 processes in Gabi 6.0.

2.3.4. Air Travel

To estimate impacts of air travel, respondents were asked to list the destinations that they had visited by airplane over the past year. The back and forth distances to these destinations from Copenhagen Airport was then estimated. For domestic flights the back and forth distance between Copenhagen Airport and Aalborg Airport was used. Adding up these distances, the aggregated distance travelled using air transportation was calculated for each respondent. Representative Ecoinvent 2.2 processes were used to account for impacts of air transportation (please refer to Table S1 in SI III for a list of LCI processes used).

2.3.5. Food Consumption

Detailed data about food consumption was collected. Respondents were asked whether they eat meat, and if so, further details about their meat consumption habits were enquired both for hot and cold served meat types. This additional information included weekly numbers of meals with meat, the type of meat (beef, pork, poultry, and seafood), and the typical quantity of meat consumed per meal.

Data regarding consumption of eggs, legumes, milk, and milk products were also collected via the questionnaire. Apart from these food items, gender specific data on the average consumption of bread, potatoes, vegetables, fruits, fat, sugar, and beverages in Denmark, were compiled from Pedersen *et al.* (2015). The mass allocation consumption patterns for vegetables and fruits were taken from Freshfel (2012).

An additional factor concerning food wastage was included in the questionnaire by asking about the percentage of the food typically being wasted in each household. Subsequently, the consumption of all food items was factorized in order to take into account these food wastages.

Food consumption related impacts were assessed and quantified using Simapro 8.0.4 and the Ecoinvent 3.1 database (refer to Table S1 in SI III for a list of LCI processes used). Custom processes were built in Simapro to model bread, vegetables and fruits. Although, Ecoinvent 3.1 is the most recent available database, processes to account for impacts related to legumes and beverages are not available in this inventory database. Hence, these food items had to be excluded from this assessment study.

2.3.6. Modeling Non-Food Products and Services

Respondents were asked to provide their monthly and yearly expenditures on personal products (*e.g.* mobile phones, cosmetics, clothes, golf equipment), and the corresponding amount they spend on products for the home (*e.g.* televisions, furniture, tools, gardening equipment). The respondents' general perceptions of their consumer behaviors were measured by asking whether they primarily buy used or new products, and whether they tend to purchase cheap (*i.e.* low end) or expensive (*i.e.* high end) items from a product range. Finally, respondents were asked about their monthly expenditure on experiences or services (*e.g.* cinema and theatre visits, membership of a sports club, restaurant visits).

It was not possible to include assessments of the impacts related with non-food products and services in the present study, since data on such diverse product and service groups is not available in the inventory databases. However, to get an idea of the magnitude of the contributions to the environmental impacts from these product and service groups, the climate burden (in terms of kg CO_2 Eq. per monetary unit spent) from Environmental Extended Input Output (EIO) tables were estimated.

3. Results and discussion

The sample size of 1281 is a good sample size (99.96% confidence level with 5% margin of error) to represent Denmark population for the year 2013. The average per person income and average per household income after tax of the sample was found to be 223,302 DKK/year and 362,014 DKK/year, respectively. In addition, the average age of the respondents was found to be 49.2 years with 75 percentile of respondents in the sample being less than 63 years. Such a sample was assessed using the PM-LCA model to estimate the environmental burden *i.e.* PIPs of the 1281 Danish residents from urbanized areas. The results provide insights into resource consumption impacts on the environment. The following sub-sections elaborate on the results and findings.

3.1. Overall result analysis - variations in the impact potentials and contribution analysis

The midpoints represent the potential environmental impacts that are accounted for by the ReCiPe 2008 method for 18 impact categories. Figure 2 shows the variation in these 18 impact categories across six components of consumption (accommodation, thermal energy, electricity, road transport, air travel, and food). Table S2 in SI III provides detailed statistical parameters for the total consumption. As is evident from Figure 2, there is little variation in the impact potentials by accommodation, thermal energy, electricity, air travel, and food across all the impact categories. On the other hand, the impact potentials resulting from road transport exhibit considerable variations compared to the other consumption components. The variations observed in the impact potentials resulting from road transportation can be attributed to the uses of private and public transportation. In addition, use of bicycle for commuting between work and home is very common in Denmark (Copenhagen City of Cyclists, 2011).

A contribution analysis was carried out to identify which components of consumption that contributes most to each impact category. Figure 3 shows a color scalar graph of contribution to impact categories by consumption component, for each of the 1281 respondents. From this graph, it can be seen that each of the respondents performs differently in different impact categories with respect to different consumption components. This is because consumption of products and services for each respondent differs both qualitatively (e.g. using more public transport, or having vegetarian diet) and quantitatively (e.g. high house area per person, higher thermal energy consumption). This creates a unique PIP for each of the 1281 respondents.

From Table 1 summarizing the contributions it is apparent that there is no single/common component of consumption that dominates the impacts across all the impact categories. The relative contribution analysis shows that Food consumption dominates (>40%) the impact contributions within eight impact categories (Agricultural land occupation, Freshwater ecotoxicity, Freshwater eutrophication, Marine ecotoxicity, Marine eutrophication, Terrestrial acidification, Terrestrial ecotoxicity, Natural land transformation). Thermal energy consumption dominates (>30%) the impact contributions within one impact categories (Ozone depletion), and road transportation dominates (>60%) impacts in two impact categories (Ionising radiation, Urban land occupation). Metal depletion and water resource depletion are equally contributed by accommodation and road transport. For the impact categories climate change, fossil depletion, human toxicity, particulate matter formation, and photochemical oxidant formation no clear dominance from any of the consumption components could be identified.

In the PM-LCA model, accommodation (construction of house) and food consumption were modelled using a multitude of processes (please refer to Table S1 in SI III). The detailed contribution analysis of elementary flows reveals that a wide range of processes contributes to the overall impact potential originating from the construction of a house. However, it is the production processes of aluminum window frames, concrete and steel that accounts for about 55-60% of the impacts in the climate change impact category; 70-75% of the impacts in human toxicity, fresh water ecotoxicity, marine ecotoxicity, freshwater eutrophication impact categories, and; 55% of the impacts in the terrestrial ecotoxicity impact category. The impacts from these three production processes are all driven by their consumption of large amounts of resources and energy (the latter of which is mainly generated from combustion of fossil fuels).

Similarly, in the food consumption component, production processes of red meat, chicken, milk, butter and electricity contribute to 90% of the impacts in all the impact categories, except for two impact categories. In the water depletion impact category, 80% of the consumption related impacts are attributed to wheat grain production processes. In the Terrestrial Ecotoxicity (TET) impact category, potato production contributes to 95% of the impacts. Such high contributions from single processes in one impact category are most likely caused by large characterization factors associated with particular elementary flows in each particular impact category. For example, the use of pesticides having high characterization factors for TET (Metam-sodium dehydrate having TET characterization factor 246 kg 1,4-DBeq./kg) in potato production makes this process a major contributing process to the TET impact category.

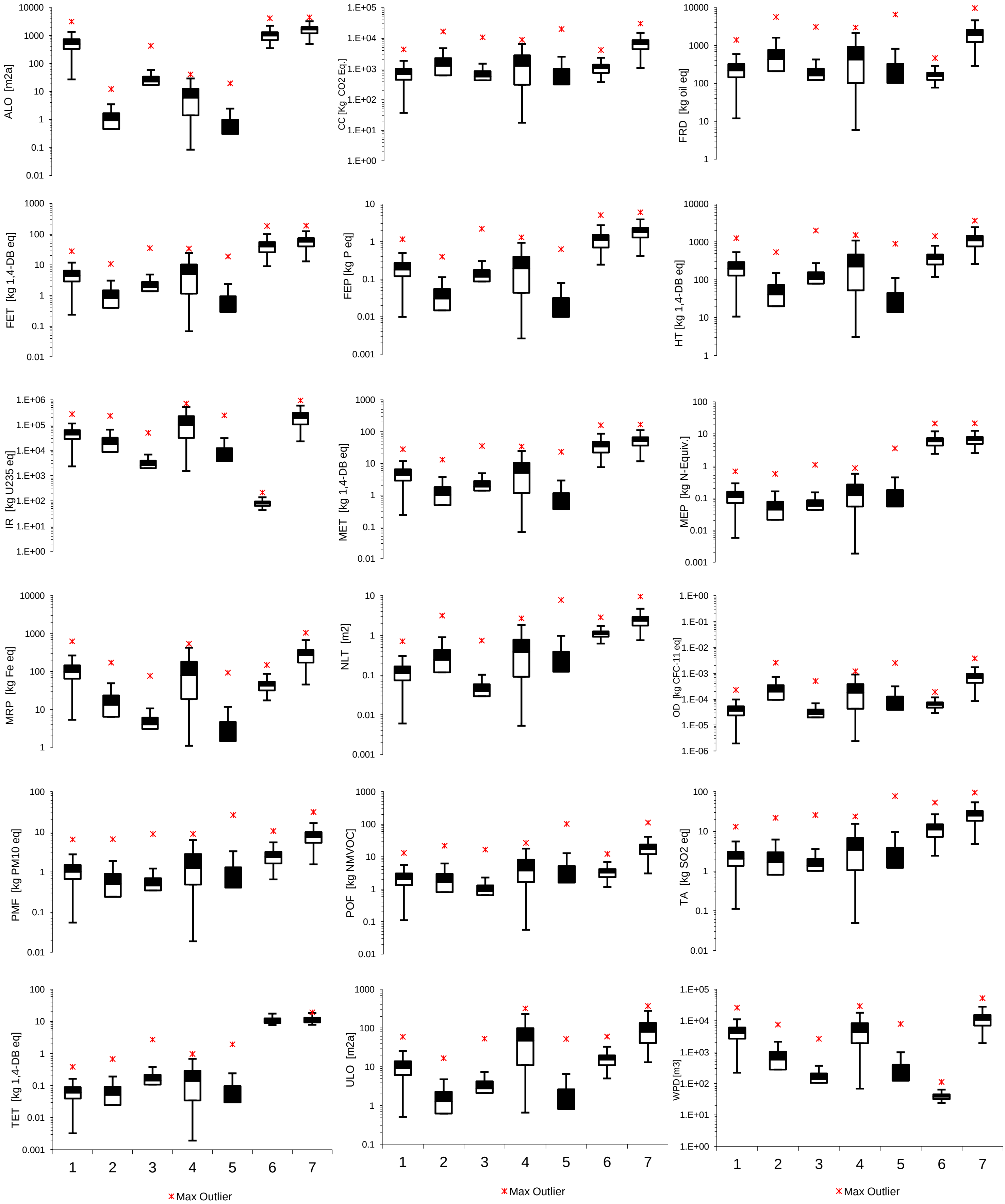

Figure 2: Variation in the impacts of consumption components and total consumption of 1281 respondents. (note that y-axis for all graphs is plotted with log-scale)

(1. Accommodation 2. Thermal energy 3. Electricity 4. Road Transport 5. Air Travel 6. Food 7. Total)

(ALO - Agricultural Land Occupation; CC - Climate Change; FRD - Fossil Depletion; FET - Freshwater Ecotoxicity ; FE - Freshwater Eutrophication; HT - Human Toxicity; IR - Ionizing Radiation; MET - Marine Ecotoxicity; MEP - Marine Eutrophication; MRD - Metal Depletion; NLT - Natural Land Transformation; OD - Ozone Depletion; PMF - Particulate Matter Formation; POF - Photochemical Oxidant Formation; TA- Terrestrial Acidification; TET - Terrestrial Ecotoxicity; ULO - Urban Land Occupation; WPD - Water Depletion)

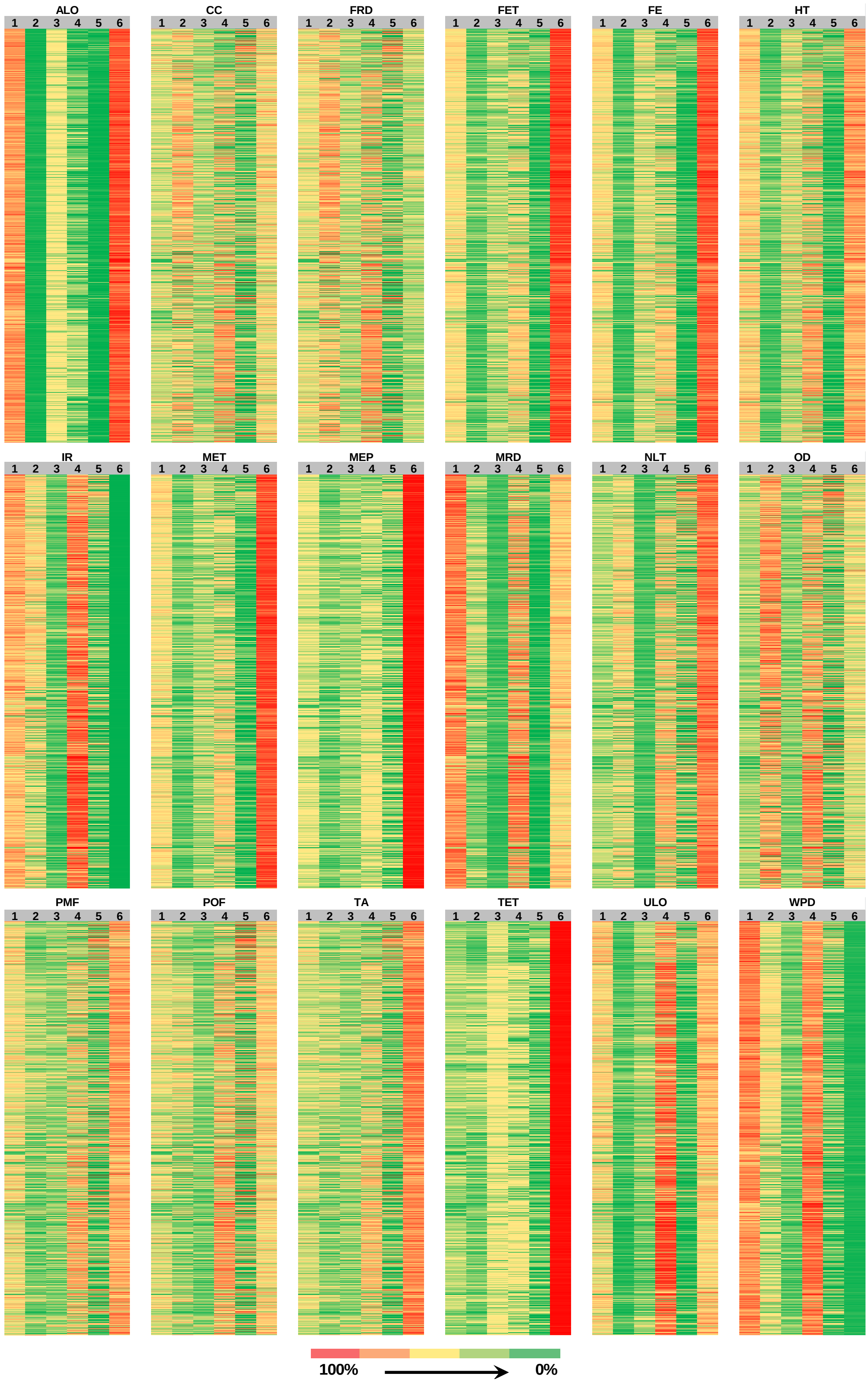

Figure 3: Contribution to impact categories by consumption component, for each of the 1281 respondents (1 - Accommodation; 2 – Thermal energy; 3-Electricity; 4 - Road Transport; 5 - Air Travel; 6- Food)

(ALO - Agricultural Land Occupation; CC - Climate Change; FRD - Fossil Depletion; FET - Freshwater Ecotoxicity ; FE - Freshwater Eutrophication; HT - Human Toxicity; IR - Ionising Radiation; MET - Marine Ecotoxicity; MEP - Marine Eutrophication; MRD - Metal Depletion; NLT - Natural Land Transformation; OD - Ozone Depletion; PMF - Particulate Matter Formation; POF - Photochemical Oxidant Formation; TA- Terrestrial Acidification; TET - Terrestrial Ecotoxicity; ULO - Urban Land Occupation; WPD - Water Depletion)

Table 1: Summary of Contribution Analysis (values in percentages)

	Accommo-dation	Thermal Energy	Electricity	Road Transport	Air Travel	Food	Total
Agricultural Land Occupation	34.6	0.1	1.9	0.5	0.0	63.0	100
Climate Change	11.6	24.2	11.6	24.1	12.1	16.4	100
Fossil Depletion	12.7	27.8	11.3	27.0	13.3	8.0	100
Freshwater Ecotoxicity	8.6	1.8	4.4	10.6	1.3	73.3	100
Freshwater Eutrophication	11.4	2.1	8.7	12.9	1.4	63.5	100
Human Toxicity	20.4	4.7	13.0	24.9	3.2	33.7	100
Ionizing Radiation	22.6	10.5	1.7	60.7	4.5	0.0	100
Marine Ecotoxicity	9.5	2.4	4.9	11.8	1.8	69.6	100
Marine Eutrophication	1.9	0.8	1.2	2.6	2.2	91.3	100
Metal Depletion	40.0	6.0	2.0	35.2	1.3	15.5	100
Natural Land Transformation	5.4	13.0	2.3	20.2	13.2	46.0	100
Ozone Depletion	5.8	35.1	5.1	31.0	14.2	8.8	100
Particulate Matter Formation	15.1	8.3	8.3	22.1	13.8	32.4	100
Photochemical Oxidant Formation	12.8	11.5	6.5	28.5	22.5	18.2	100
Terrestrial Acidification	9.2	8.4	7.3	17.1	12.2	45.8	100
Terrestrial Ecotoxicity	0.6	0.6	1.8	1.6	0.7	94.6	100
Urban Land Occupation	11.5	1.7	4.1	63.4	2.3	17.0	100
Water Depletion	40.8	6.4	1.7	48.0	2.8	0.3	100

The comparison of the contribution results with other studies reveals agreement of the results from the study at hand with already published studies. In one of the macro scale studies, it is recognized that the main contributors of environmental impacts (Abiotic depletion, Global warming, Photo-chemical oxidation, Acidification, Eutrophication, Human toxicity potential, Ecotoxicity) in the EU countries are related to household consumption, specifically food and beverages (20-60%), accommodation (20-35%), transportation (15-25%), and other products consumed such as clothing (20-30%) (Tukker et al., 2006). Druckman and Jackson (2009) estimated the carbon footprint of UK's average households for the year 2004. The UK study yielded a 26% contribution from Recreation and leisure (which includes aviation related emissions), 15% from Food and catering, 15% from heating (*i.e.* originating from thermal energy and electricity) of accommodation spaces, 12% from households (including house and electricity consumption for lighting), and 11% from clothing including footwear. In the study presented by Schmidt and Muños (2014) on the consumption of Danish households it was reported that energy (thermal energy and electricity) is one of the main contributors to the household carbon footprint, which aligns well with the findings of our study. In terms of further alignment with the Tukker et al. (2006) and Druckman and Jackson (2009) studies, our study also reveals that food consumption and energy (electricity and thermal energy) consumption are the main contributors to the environmental burden of urban residents in Denmark.

3.2. External validation - climate change potential comparison

An attempt to validate the obtained results of our study with already published results was made. However, to the best of our knowledge there has been no similar study undertaken in the past covering all the consumption components included in our study. Neither has any study been located providing results with the same detail/resolution and completeness as presented here. Only for the climate change burden associated with consumption patterns comparable results were found.

The comparison of the climate change burden yielded an unclear picture, since the results obtained in our study both aligned and misaligned with previously published results on the climate change burden of consumption patterns. Accounting for emissions of the seven consumption components of urban inventories (covering electricity, thermal energy and industrial fuels, industrial processes, ground transportation, aviation, marine, and waste) Kennedy *et al.* (2009) estimated a climate change burden in the range of 4.2 to 21.5 tCO_2

eq./capita/year for ten cities. The city in Kennedy *et al.* (2009) considered most comparable to Danish Cities was Geneva exhibiting a consumption based climate change burden equaling 7.8 tCO_2eq./capita/year. Our study estimates the consumption based average climate change burden to 6.8 tCO_2 eq./capita/year (refer to Figure 2, graph 2), accounting for emissions related to accommodation, energy, road transport, air travel, and food.

Tukker *et al.* (2014) reports a Danish climate change burden of 19.0 tCO_2 eq./capita/year based on Input-Output (IO) analysis. NIRAS (2011) employed hybrid IO based analysis for carbon footprinting of Danish municipalities yielding a climate change burden of 19.3 tCO_2 eq./capita/year emissions for Danish residents, accounting for food, accommodation, transportation, shopping, services, and public functions. Schmidt and Muños (2014) reported a carbon footprint of 15 tCO_2 eq./capita/year for Danish residents for the year 2013. The IO based results should be expected to be higher than the value estimated through the attributional LCA approach applied in our study, due to the wider scope and different cut-off criteria applied in IO analysis. Two other IO model based studies (Baiocchi *et al.*, 2010; Druckman and Jackson, 2009) reported average carbon footprints (CFP) for UK households. Druckman and Jackson (2009) report CFPs of 9 tCO_2 eq./capita/year while Baiocchi *et al.* (2010) report 8.3 tCO_2 eq./capita/year. In one of the recent comprehensive reviews by Goldstein et al. (2016) on CFPs of urban food consumption it is reported that on a worldwide average food consumption by urban residents (solely) yields a climate burden of 1.9 tCO2 eq./capita/year. In our study we found an average CFP of 1.12 tCO_2 eq./capita/year for food consumption.

It is, however, difficult to provide more general conclusions on the relevance, validity and significance of the results we have obtained relative to the above reviewed studies. Primarily because different assessment approaches (*i.e.* attributional LCA, consequential LCA or IO/hybrid LCA) inevitably will lead to different results. In addition, CFPs do not necessarily work as a validation proxy for the other impact categories (Laurent et al., 2012, 2010), and hence, CFPs cannot be used as validation points for the other impact categories included in our study.

3.3. Comparison of behavioral factors on environmental impacts

One of the aims of this work was to quantify the effect of behavioral factors on environmental impacts related to private consumption. The comparison of behavioral factors was made on two aspects. Firstly, vegetarian and non-vegetarian diets were compared. We found that respondents with non-vegetarian diets (*n* = 1037) on average have a 2.2 times larger contribution within the food consumption component (see Figure 4) to all the impact categories included in our study compared to those of the respondents preferring a vegetarian diet (*n* = 244). In terms of the total impacts of the consumption components (sum of the six components) a similar trend was observed. We found that the ratio of the total impacts of non-vegetarian respondents and vegetarian respondents amounts to 1.6. These findings aligns well with previous studies specifically focusing on Green House Gas (GHGs) Emissions from diets (Green *et al.*, 2015; Meier and Christen, 2013; Saxe, 2014; Saxe *et al.*, 2013; Tilman and Clark, 2014). Specifically, a ratio of 1.3 and 1.7 was reported between the $CO_{2eq.}$ emissions per capita per year of non-vegetarian and vegetarian diets by Meier and Christen (2013) and Tilman and Clark (2014), respectively. All of these studies focused on comparing climate change burdens (*i.e.* GHG emissions). Our study is hence the first of its type to report that the environmental impact of non-vegetarian diets across a multitude of impact categories (18 midpoints derived from ReCiPe method) is considerably and potentially significantly higher (almost by factor of 2 in all 18 impact categories) than for vegetarian diets.

Another behavioral factor studied was related to use of public transportation. As Copenhagen is a city with well-developed public transportation systems, as well as "City of Cyclists" (City of Copenhagen, 2011), we found it interesting to quantify the impact variation among respondents owning one or more private car(s) and respondents with no private car. As shown in Figure 4, the transportation component related impacts across all impact categories of respondents with private cars are uniformly much higher (by factor of 5.1 on average). Comparing the total consumption based impacts (*i.e.* sum of the six components) the ratio of the total impacts for respondents with private cars relative to the respondents with no private car was found to be 1.6 (see Figure 4).

The environmental performance of different household sizes was also assessed. Respondents were grouped in sets according to the number of residents per household and the average normalized Climate Change Potential (kg $CO_{2eq.}$) for each household size group was assessed. As can be observed from Figure 5, there appears to be a (negative) linear relationship between the total climate burden per person and the family size, meaning that respondents from larger households on average are associated with a lower climate burden than respondents from smaller households. Approximately, a 25-30% saving is obtained when moving from 1 person households to 6 person households, meaning that app. 4-5% climate burden can be saved per person every time a household increases by 1 person. This is most likely due to economy of scales. The impacts per person resulting from accommodation and energy consumption are also correlated negatively with the household size, revealing that the smaller the number of residents occupying an accommodation unit, the higher the impacts related with the accommodation and energy components of the consumption pattern. Hence, this study is consistent with the finding of EEA (2005); that one of the factors contributing to increased consumption and the associated environmental impacts is the growing tendency of households to become smaller.

It is likely that a multitude of factors related to behavior and social aspects may cause variations in the consumption related impacts. Past studies have shown that factors such as locality and type of dwelling (Newton and Meyer, 2012) and attitudinal factors such as environmental awareness (Gilg and Barr, 2006; Newton and Meyer, 2013) also affect the environmental impacts posed by urban residents.

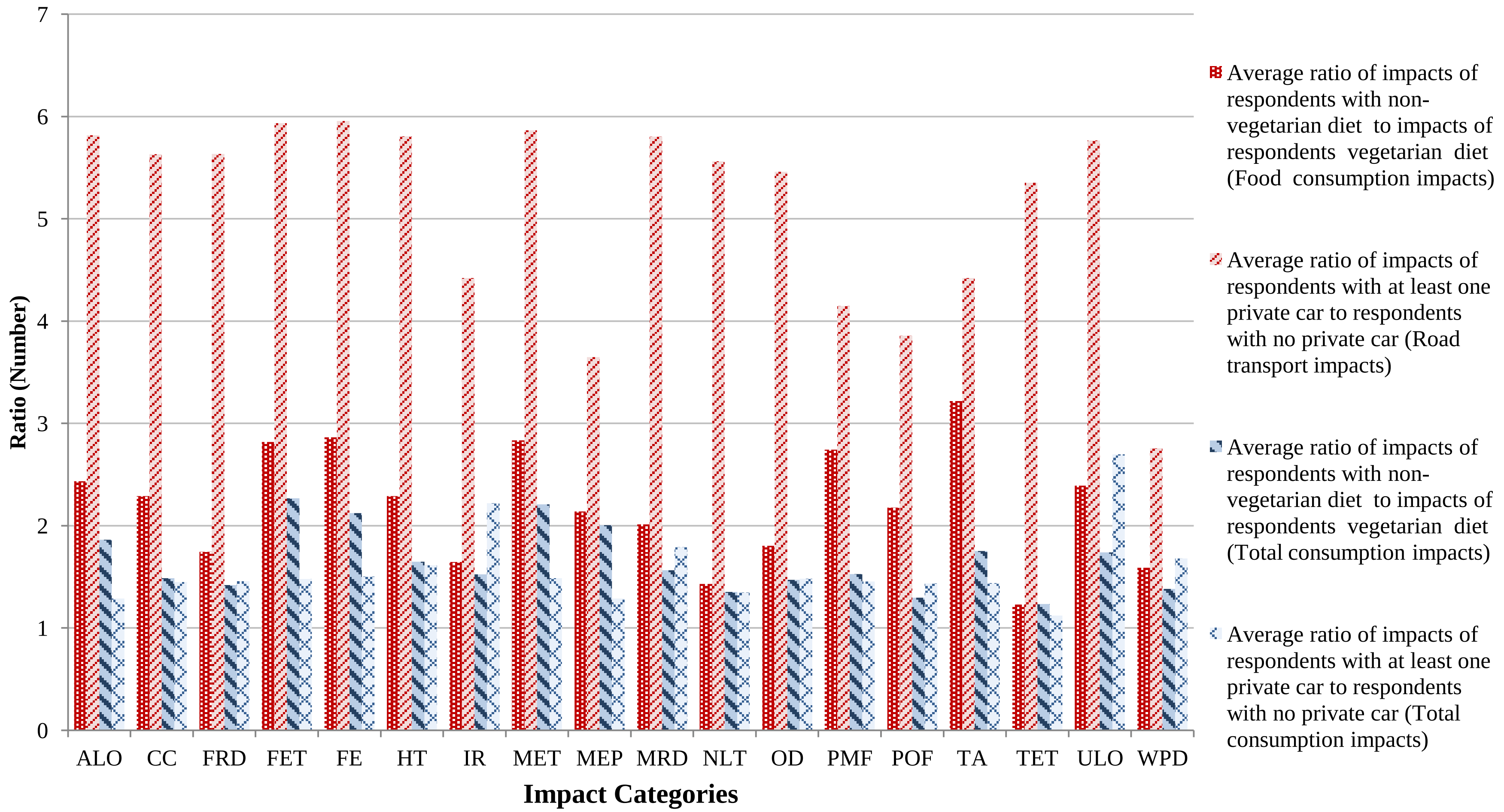

Figure 4: Effect of behavioral factors on environmental impacts (comparison of impacts from respondents with vegetarian and non-vegetarian diet as well as comparison of impacts from respondents using public transport versus respondents using private transport).

(ALO - Agricultural Land Occupation; CC - Climate Change; FRD - Fossil Depletion; FET - Freshwater Ecotoxicity ; FE - Freshwater Eutrophication; HT - Human Toxicity; IR - Ionizing Radiation; MET - Marine Ecotoxicity; MEP - Marine Eutrophication; MRD - Metal Depletion; NLT - Natural Land Transformation; OD - Ozone Depletion; PMF - Particulate Matter Formation; POF - Photochemical Oxidant Formation; TA- Terrestrial Acidification; TET - Terrestrial Ecotoxicity; ULO - Urban Land Occupation; WPD - Water Depletion)

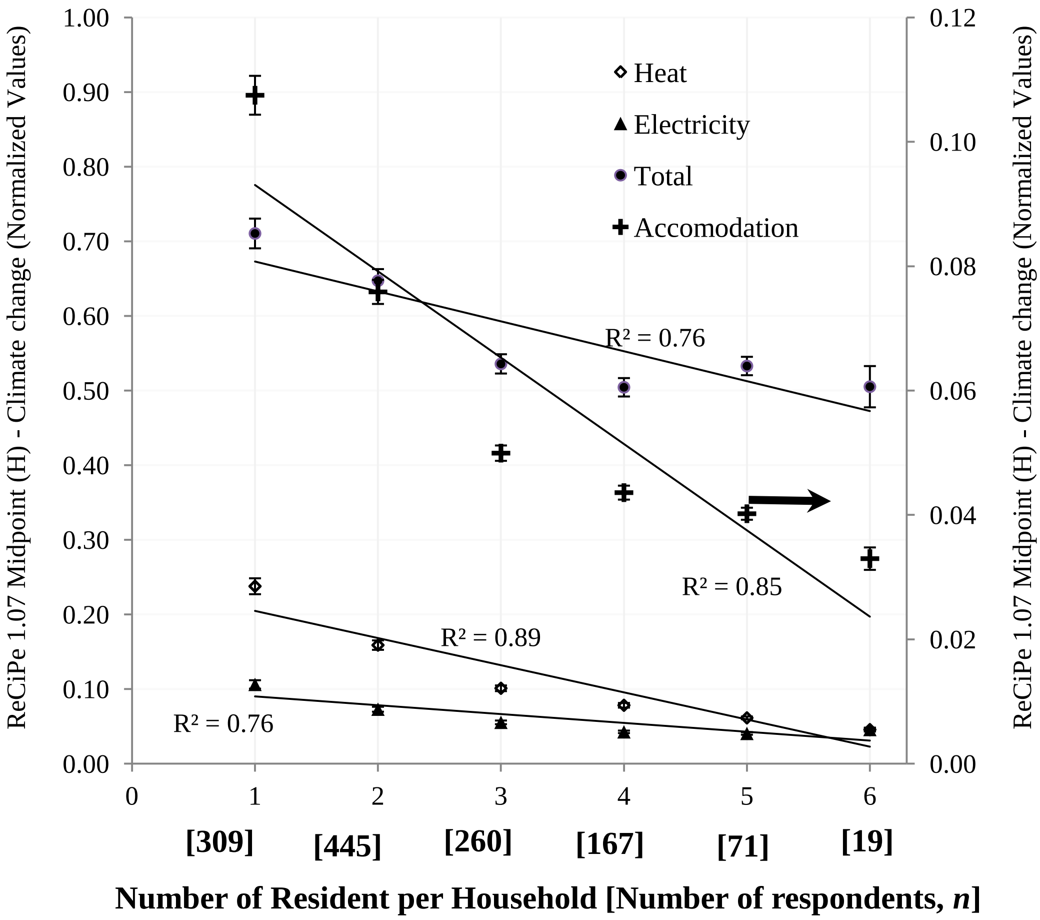

Figure 5: Effect of the number residents living in a household on different housing and energy consumption components as well as overall consumption. The values on Y-axis are the average of normalized per capita values of climate change potential for the different households' sizes.

3.4. Accounting for non-food products and services

The present study attempted to include as much as possible of the resource consumption related impacts of urban residents. In order to achieve this, a hybrid approach merging two software solutions with the latest databases (Gabi 6.0 with Ecoinvent 2.2 and Simapro 8.0.4 with Ecoinvent 3.1) was employed. Nevertheless, due to limitations in inventory data, the study could not include impacts related to consumption of non-food products and services (*e.g.* clothing, electronics products, household equipment, hotels and restaurants, public services, and health services). Given that, Danish urban residents spend a considerable share of their income on non-food products and services (Statistics Denmark, 2015b) these should be expected to contribute noticeable to the consumption related environmental burden.

To investigate the significance of the impacts from non-food products and services excluded from our study the IO approach was applied. The EU27 and Denmark IO databases from Simapro 8.0.4 were used to estimate the CFP of recreational products and services. Only the relevant products and services from these databases were considered (*i.e.* those that were excluded due to the process based approach applied in this study). The IO data located were representative for the year 2003. Therefore, corrections related to inflation and base price conversion were applied for the expenditure values obtained from the questionnaire.

Based on this analysis, we found that consumption of personal products (clothing and communication) on average cause emissions of 763 kg CO_2 eq./capita/year, whereas consumption of home products (appliances and equipment, radio, television and communication equipment, furniture, and other manufactured goods) on average cause 341 kg CO_2 eq./capita/year of emissions. Services, (such as post services and telecommunication, computer and related services, health and social work, membership organizations, recreational and cultural services, and leisure), account for a climate change burden of 185 kg CO_2 eq./capita/year. In total, the products and services excluded from our process based approach on average account for a climate change burden of 1288 kg CO_2 eq./capita/year. Hence, it is estimated that the consumption related climate burden assessed in our study are accounting for approximately 80-85% of total climate burden posed by urban Danish resident.

As earlier mentioned, our study does not include impacts related to consumption of beverages, such as tea, coffee, soft drinks, beer, wine and alcoholic drinks. It is however possible to estimate a range of CO_2 emissions from past studies specifically focusing on beverages (*e.g.* Quantis, 2010; Saxe *et al.* 2013; Rugani *et al.* 2013). A value of 250-300 kg additional CO_2 emissions should most likely be added to the consumption related climate burden presented in this paper (6841 kg CO_2/capita/year) on top of the 1288 kg CO_2 eq./capita/year stemming from non-food products and services. In sum, applying a value for beverages of 275 kg CO_2/capita/year, the PM based climate burden for Danish urban residents is estimated to 8404 kg CO_2/capita/year.

3.5. Limitations of the study and future prospects

The present study was based on empirical data from 1281 respondents. The data collected through the questionnaire survey were further processed to generate the LCIs and subsequently used for the LCIAs. During this process, various assumptions and modelling choices were made giving rise to some level of uncertainty of the results we present, further limiting the applicability of the results. Below the major assumptions or modelling choices of this research are listed:

1. As mentioned in the methodology section, respondents were asked to choose from a range of interval values (*e.g.* 500-1000) for each consumption item covered in the questionnaire. As part of the data processing these were then converted to interval mid-points (*e.g.* 750). This constitutes one source of uncertainty. However, asking respondents to provide precise values in the questionnaire would arguably have led to a considerably lower response rate.
2. Two software solutions with two different versions of the Ecoinvent database have been used for producing the results of the study. This also constitutes a source of uncertainty, as it is well proven that there are differences between the results obtained using different software products and databases (Herrmann and Moltesen, 2015; Speck et al., 2015).
3. Due to unavailability of LCI processes in the Ecoinvent 2.2 database related to other thermal energy sources, it was assumed that respondents use district heating for heating their homes. For the 19.17% respondents in the data set who do not use district heating for heating their home, considerable data processing was conducted to account for price variations between different thermal energy sources in terms of the amount of mega joules which can be purchased per Danish Krone (DKR).
4. We have used only one LCIA method, ReCiPe 2008 to obtain the results. However, it is necessary to see the effect of different LCIA methods on the results. This extensive

comparison analysis of influence on the results of the choice of impact assessment methodology is however considered beyond the scope of this paper.

5. In many instances, secondary data sources have been used to enable a complete LCI (e.g. mass distribution of vegetables and fruits in diets, flight distances, and data related to public transport in Denmark).

Apart from this, there are many other assumptions and secondary data that have been used in this study (refer to SI II for details). The results from the present study shall be interpreted in the light of these assumptions and associated uncertainties.

In the present study, endpoints and single scores have not been specifically reported. Looking at the complexity of the interpretations, the endpoint and single score results will be published separately complimented with an additional analysis of sustainable behavior.

The results of the present study are multifold and there are many aspects that still need to be addressed and assessed. For example, the results can be utilized for the development of 'Integrated Product Policies.' as reported in Nissinen *et al.* (2007). The results can also be useful in developing a more realistic resource consumption cap for urban residents based on life cycle thinking, rather than mere material intensity, as proposed by Lettenmeier *et al.* (2014).

The results of our study will help the Danish and other comparable populations to identify and prioritize the steps towards reducing their environmental impacts. Further analyses of the perceptions of citizens with respect to resource consumption and its impact on the environment will be carried out, in order to link perceived life quality to consumption patterns, as well as to the overall environmental impacts quantified in our study. In addition, an investigation of the relation between sustainable behavior and the environmental burden of respondents is currently being undertaken.

4. Conclusions

The study presented here reports on the environmental burden of Danish urban residents. The computation was based on the PM-LCA approach, which is one out of several ways (consequential LCA and pure IO may also be used) to calculate the burden of Danish urban residents. No matter the approach used; assessment method specific uncertainties are introduced. For the primarily attributional based LCA approach applied here, the main uncertainty is the parts of the systems that have been cut off. On the other hand, for consequential LCA the largest uncertainties introduced will most likely come from the modelling of the expanded part of the system and in IO analysis lack of indicators and the conversion of monetary units into impact potentials.

Based on the PM-LCA model, we found that, due to qualitative differences in the consumption of resources and variation in the quantity of resources consumed, each urban resident exhibits a unique PIP. The analysis of PIPs of 1281 urban residents showed that food consumption is the most dominating consumption component in the PM of urban resident in most of the impact categories. The study on effect(s) of simple behavioral factors on the environmental burden related with consumption revealed that choice of diet, use of private car, and household size do affect the environmental burden posed by urban residents.

The present study focused on analyzing human life styles in the context of environmental and human health impacts, as well as resource consumption, in order to identify hot spots (*i.e.* most evident optimization points) for potential reduction of consumption related environmental burdens. The results of the study are considered useful in: 1) benchmarking resource consumption; 2) creating awareness among urban residents about (un)sustainable consumption; 3) developing emission caps at personal consumption level, and; 4) framing of policies for green products and services. In spite of the analyses conducted and the results presented here, further analysis of the data is required in order to ascertain the relation between consumer perceptions in terms of resource consumption and associated impacts on the environment. In addition, there is a need to investigate the influence of other attitudinal and behavioral factors on consumption induced environmental impact profiles.

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Personal-Metabolism (PM) coupled with Life Cycle Assessment (LCA) Model: Danish Case Study

Supplementary Information I[#]

Questionnaire

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About yourself and your household (demographic factors)

1. What gender are you?

☐ Man

☐ Woman

2. What year were you born? ________________

3. Who do you live with at the moment?

Include only adults who you share address with.

☐ With partner / spouse

☐ Alone (possibly with children)

☐ With one or both parents

☐ Other (e.g. roommate or collective)

4. How many adults and children live in the household??

Include only adults who you share address with.

Number of adults (DO NOT COUNT yourself): ____________________

Number of children: ____________________

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5. What is your personal income after taxes??

Your total personal income after tax last month

- ☐ Nothing
- ☐ Less than 2.500 DKR
- ☐ 2.500 to 5.000 DKR
- ☐ 5.000 to 10.000 DKR
- ☐ 10.000 to 15.000 DKR
- ☐ 15.000 to 20.000 DKR
- ☐ 20.000 to 25.000 DKR
- ☐ 25.000 to 30.000 DKR
- ☐ 30.000 to 40.000 DKR
- ☐ 40.000 to 50.000 DKR
- ☐ 50.000 to 75.000 DKR
- ☐ 75.000 to 100.000 DKR
- ☐ More than 100.000 DKR

Your total personal income after tax over the past year

- ☐ Nothing
- ☐ Less than 30.000 DKR
- ☐ 30.000 to 60.000 DKR
- ☐ 60.000 to 120.000 DKR
- ☐ 120.000 to 180.000 DKR
- ☐ 180.000 to 240.000 DKR
- ☐ 240.000 to 300.000 DKR
- ☐ 300.000 to 360.000 DKR
- ☐ 360.000 to 480.000 DKR
- ☐ 480.000 to 600.000 DKR
- ☐ 600.000 to 900.000 DKR
- ☐ 900.000 to 1.200.000 DKR
- ☐ More than 1.200.000 DKR

6. What is your household's total income after taxes?

If you live alone, skip to question 7

Total household income
after tax in the last month (all adults)

- ☐ Nothing
- ☐ Less than 5.000 DKR
- ☐ 5.000 to 10.000 DKR
- ☐ 10.000 to 20.000 DKR
- ☐ 20.000 to 30.000 DKR
- ☐ 30.000 to 40.000 DKR
- ☐ 40.000 to 50.000 DKR
- ☐ 50.000 to 60.000 DKR
- ☐ 60.000 to 80.000 DKR
- ☐ 80.000 to 100.000 DKR
- ☐ 100.000 to 150.000 DKR
- ☐ 150.000 to 200.000 DKR
- ☐ More than 200.000 DKR

Total household income
after tax over the past year (all adults)

- ☐ Nothing
- ☐ Less than 60.000 DKR
- ☐ 60.000 to 120.000 DKR
- ☐ 120.000 to 240.000 DKR
- ☐ 240.000 to 360.000 DKR
- ☐ 360.000 to 480.000 DKR
- ☐ 480.000 to 600.000 DKR
- ☐ 600.000 to 720.000 DKR
- ☐ 720.000 to 960.000 DKR
- ☐ 960.000 to 1.200.000 DKR
- ☐ 1.200.000 to 1.800.000 DKR
- ☐ 1.800.000 to 2.400.000 DKR
- ☐ More than 2.400.000 DKR

7. What is the longest education that you and your parents have completed? (Tick yourself, your mother and your father)

	You	Father	Mother
High school			
Gymnasium, HF, HTX, HHX or HG			
Craftsman			
Short higher education (less than 3 years of study)			
Medium long higher education (3-4 years of study)			
Longer higher education (more than 4 years of study)			
PhD or doctorate			
Do not know			

8. What is your present primary occupation??

☐ Independent
☐ Assisting spouse
☐ Academic/office worker (e.g., commercial, academic, and office work, teacher, educator)
☐ Manager
☐ Unskilled worker (no education)
☐ Craftsman (e.g. carpenter, tailor, baker)
☐ Military service
☐ Student
☐ Unemployed
☐ On leave (maternity, illness, etc.)
☐ Pensioner, early retirement

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Environmental Sustainability

On the following pages you will find a list of questions for your housing, transportation, vacation, food, and spending. We use this information to calculate how much CO2 your current lifestyle emits. Some of the questions may be a little difficult, but try to be as precise as possible.

Housing

We need your address to view information about your home (e.g. living space and heating agent) in the public inventory of buildings and homes in the BBR. This saves you from having to fill in the information yourself.

Please note that your information will be kept strictly confidential.

9. What address do you live on?

Road	
House number	
Floor / side (e.g. 4th to the right)	
Zip code	

10. Do you live for rent?

☐ Yes

☐ No, I/we own the property (including owners of cooperative housing)

11. What year did you move into your home?

Enter year: ______________________

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12. Do you own a holiday home (cottage)?

☐ Yes

☐ No

If you do not own a summer house (cottage), skip to question 15.

13. What is the address of your holiday?

Road	
House number	
Postal code	

14. What year did you buy your holiday home?

Enter year: ________________________

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15. What was the household's heating bill in 2013?

Include only the heat consumption of your primary residence (not your vacation house)

☐ 0 DKR
☐ Less than 250 DKR
☐ 250 to 500 DKR
☐ 500 to 1.000 DKR
☐ 1.000 to 2.000 DKR
☐ 2.000 to 4.000 DKR
☐ 4.000 to 8.000 DKR
☐ 8.000 to 12.000 DKR
☐ 12.000 to 16.000 DKR
☐ 16.000 to 24.000 DKR
☐ 24.000 to 32.000 DKR
☐ More than 32.000 DKR

If you have any comments on your heat consumption, please write them here...

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16. What was the household's electricity consumption in 2013?

Include only the electricity consumption of your primary residence (not your vacation house)

- ☐ 0 DKR
- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1.000 DKR
- ☐ 1.000 to 2.000 DKR
- ☐ 2.000 to 4.000 DKR
- ☐ 4.000 to 8.000 DKR
- ☐ 8.000 to 12.000 DKR
- ☐ 12.000 to 16.000 DKR
- ☐ 16.000 to 24.000 DKR
- ☐ 24.000 to 32.000 DKR
- ☐ More than 32.000 DKR

Or…

- ☐ 0 kWh
- ☐ Less than 125 kWh
- ☐ 125 to 250 kWh
- ☐ 250 to 500 kWh
- ☐ 500 to 1.000 kWh
- ☐ 1.000 to 2.000 kWh
- ☐ 2.000 to 4.000 kWh
- ☐ 4.000 to 6.000 kWh
- ☐ 6.000 to 8.000 kWh
- ☐ 8.000 to 12.000 kWh
- ☐ 12.000 to 16.000 kWh
- ☐ More than 16.000 kWh

If you have any comments on your electricity consumption, please write them here…

If you rent, skip to question 19

17. How much have you spent on larger exterior and interior renewal and maintenance of the home in all the years you have lived in there?

☐ Less than 10.000 DKR
☐ 10.000 to 25.000 DKR
☐ 25.000 to 50.000 DKR
☐ 50.000 to 100.000 DKR
☐ 100.000 to 200.000 DKR
☐ 200.000 to 400.000 DKR
☐ 400.000 to 600.000 DKR
☐ 600.000 to 800.000 DKR
☐ More than 800.000 DKR

18. Have renewals and maintenance of the home been conducted by hired craftsmen, or have you done it yourself?

☐ We have always or almost always hired craftsmen to make renovations to our home
☐ We have, in most cases, hired craftsmen to make renovations to our home
☐ Approximately 50/50
☐ We have made most renovations of our home ourselves
☐ We have made all or almost all renovations of our home ourselves
☐ We have not renovated our home

If you have any comments on how your house is built, please write them here…

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Transport

19. How many registered vehicles do you have in your household?

(Indicate the number of each type of vehicle. Write "0" if you / I do not own the vehicle).

	Number of
Cars	
Shared cars	
Motorcycle	
Scooters / Mopeds	

20. If you / I'm part of a car sharing scheme, just enter how many people you / I share cars with.

Number of people you share the car with: ____________________

If you do not own a registered vehicle or participate in a car sharing scheme, skip to question 23.

21. Which vehicle do you primarily use?

Registration (license plate): ________________________________

If you cannot remember the registration number, please enter instead:

Brand (e.g. Toyota): _____________________________________

Model (e.g. Corolla): ____________________________________

Production year: ____

22. What year did you buy your primary vehicle?

Enter Year: ______________________

23. How many kilometers have you, all together, driven over the past year?

Include driving both your own and others' car as driver and as a passenger. Include private car and driving to and from work / school, but not work related travel (during working hours).

☐ Less than 200 km.
☐ 200 to 500 km.
☐ 500 to 1.000 km.
☐ 1.000 to 2.500 km.
☐ 2.500 to 5.000 km.
☐ 5.000 to 10.000 km.
☐ 10.000 to 15.000 km.
☐ 15.000 to 20.000 km.
☐ 20.000 to 30.000 km.
☐ More than 30.000 km.

If you currently do not go to work or training, skip to question 26.

24. How far do you have to your workplace or your school?

☐ 0-2 km
☐ 2-5 km
☐ 5-10 km
☐ 10-20 km
☐ 20-30 km
☐ 30-50 km
☐ 50-75 km
☐ Over 75 km
☐ Working at home

25. By which type of vehicle do you primarily get to work or school?

☐ Car

☐ Motorcycle, scooter or moped

☐ Public Transportation

☐ Bicycle

☐ I walk or run

☐ I ride with other people

26. How much do you spend a year on public transportation?

☐ 0-100 DKR

☐ 100-500 DKR

☐ 500-1.000 DKR

☐ 1.000-2.500 DKR

☐ 2.500-5.000 DKR

☐ 5.000-10.000 DKR

☐ 10.000-15.000 DKR

☐ 15.000-20.000 DKR

☐ 20.000-25.000 DKR

☐ More than 25.000 DKR

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Vacation

27. Where have you been on holiday by plane this past year?

Notes: the destinations you have flown to the holiday in 2013 and 2014, and when you were away. If you have not flown in 2013/2014, skip to the next question.

Where have you been on holiday by plane? (Write country or city until you have flown to)	When did you leave? (Enter month and year)

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Food

28. (Do you eat meat?)

If you do not eat meat, then skip to question 33.

29. How many hot meals with meat do you typically eat per week?

Enter the number of hot meals for each type of meat. For example if you eat hot dishes with beef twice a week and fish once a week, mark 2 in beef and veal and 1 in seafood.

Type of meat	Number of meals per week										
	0	1	2	3	4	5	6	7	8	9	10
Beef and veal											
Pork											
Poultry											
Seafood											

30. How many grams of meat do you eat in a typical hot meal?

- ☐ 0-25 gram
- ☐ 25-50 gram
- ☐ 50-75 gram
- ☐ 75-100 gram
- ☐ 100-150 gram
- ☐ 150-200 gram
- ☐ 200-250 gram
- ☐ 250-300 gram
- ☐ More than 300 gram

1 neck chop / skinkeschnitzel weighs about 115-150 g
1 pork chop (1-1½ cm thick) weighs about 65-95 g
1 meatball weighs about 30-65 g
1 beef steak (fillet / loin fillet) weighs about 125-175 g
1 entrocote / medallion (cow / calf) weighs about 150-200 g
1 veal cutlet / kalveschnitzel weighs about 125-175 g
1 chicken breast fillet weighs about 140 g
1 chicken weighing about 190 g
1 fish fillet / fish steak weighs about 70-125 g
1 fish ball weighs about 60 g

31. How many grams of beef, veal and pork cold cuts do you eat on average per day?

- ☐ Nothing
- ☐ 0-20 gram
- ☐ 20-40 gram
- ☐ 40-60 gram
- ☐ 60-80 gram
- ☐ 80-100 gram
- ☐ 100-150 gram
- ☐ 150-200 gram
- ☐ More than 200 gram

1 slice of ham cold cuts weighs about 10-20 g
1 slice weighing about hamburgryg 10-20 g
1 slice of smoked fillet / corned beef weighs about 10-20 g
1 slice of sausage weighs about 5-10 g
1 slice of roast beef weighs about 10-20 g
1 medium portion liver paste / pate weighs about 20-25 g
1 medium portion of meat / sausage weighs about 10 g

32. How many grams of chicken and fish products do you eat on average per day?

- ☐ Nothing
- ☐ 0-20 gram
- ☐ 20-40 gram
- ☐ 40-60 gram
- ☐ 60-80 gram
- ☐ 80-100 gram
- ☐ 100-150 gram
- ☐ 150-200 gram
- ☐ More than 200 gram

1 slice of cod roe weighs about 25 g
1 medium portion mackerel in tomato weighs about 40 g
1 medium portion of marinated herring weighs about 30 g
1 medium portion tuna weighing about 50 g
1 medium portion of shrimp / seafood weighs about 30 g
1 slice of chicken / turkey cold cuts weighs about 10-20 g

33. How many eggs do you typically eat in a week (include also eggs used in meals)?

0	1	2	3	4	5	6	7	8	9	10+

34. How many meals with legumes (beans, lenses etc.) do you typically eat a week?

0	1	2	3	4	5	6	7	8	9	10+

35. How many grams of dried legumes do you use in a typical meal with legumes?

☐ Nothing, I do not eat legumes
☐ 0-25 gram
☐ 25-50 gram
☐ 50-75 gram
☐ 75-100 gram
☐ 100-125 gram
☐ 125-150 gram
☐ 150-175 gram
☐ 175-200 gram
☐ More than 200 gram

1 deciliter dried beans weighs about 80 g
1 deciliter dried yellow peas weighs about 80 g
1 deciliter dried chickpeas weighs about 75 g
1 deciliter dried lentils weighs about 75 g

36. How many grams of milk and milk products do you consume on average a day?

☐ Nothing
☐ 0-200 gram
☐ 200-400 gram
☐ 400-600 gram
☐ 600-800 gram
☐ 800-1000 gram
☐ 1000-1200 gram
☐ 1200-1400 gram
☐ 1400-1600 gram
☐ More than 1600 gram

1 liter of milk / cocoa weighs about 1000g
1 liter of yogurt weighs about 1000g
1 liter of A38 / junket weighs about 1000g
1 liter of sour milk / ylette weighs about 1000g
½ liter Cultura / Gaio weighs about 500 g
½ liter of sour cream / quark weighs approximately 500 g

37. How many grams of cheese and cheese products do you eat on average per day?

☐ Nothing
☐ 0-20 gram
☐ 20-40 gram
☐ 40-60 gram
☐ 60-80 gram
☐ 80-100 gram
☐ 100-150 gram
☐ 150-200 gram
☐ More than 200 gram

1 write factory cut cheese weighs about 18-24 g
1 slice of cheese cut with a cheese slicer weighs about 8 g
1 slice of cheese, sliced cheese string weighs about 15-20 g
1 cheese haps weighs about 18 g
1 tablespoon cream / cottage cheese weighs about 15 g
*1 diced feta cheese (1.5 * 1.5 * 1.5 cm) weighing about 4 g*

38. How much of the food you buy in your household is thrown out?

☐ Virtually none (0-5%)
☐ Only a little (5-10%)
☐ A portion (10-15%)
☐ Much (15-20%)
☐ Very much (about 20%)

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Personal consumption of goods and services

39. How much do you spend on average on items / products a month?

Set both the amount you spend on things for yourself (e.g. mobile phone, cosmetics, clothes, golf equipment, etc.), and the amount you spend on things for the home (e.g., televisions, furniture, tools, gardening equipment, etc.). If you buy things with your partner or other, please enter only the amount you use. Do not include cars and air travel and other experiences / services.

Average amount spent on products for myself a month

- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1000 DKR
- ☐ 1000 to 2000 DKR
- ☐ 2000 to 4000 DKR
- ☐ 4000 to 6000 DKR
- ☐ 6000 to 8000 DKR
- ☐ 8000 to 10.000 DKR
- ☐ More than 10.000 DKR

Average amount I use on products for the home a month

- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1000 DKR
- ☐ 1000 to 2000 DKR
- ☐ 2000 to 4000 DKR
- ☐ 4000 to 6000 DKR
- ☐ 6000 to 8000 DKR
- ☐ 8000 to 10.000 DKR
- ☐ More than 10.000 DKR

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40. How much money have you spent on products for yourself and your home the last 14 days?

Amount I spent on things for myself the last 14 days

- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1000 DKR
- ☐ 1000 to 2000 DKR
- ☐ 2000 to 4000 DKR
- ☐ 4000 to 6000 DKR
- ☐ 6000 to 8000 DKR
- ☐ 8000 to 10.000 DKR
- ☐ More than 10.000 DKR

Amount I spent on things for my home the last 14 days

- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1000 DKR
- ☐ 1000 to 2000 DKR
- ☐ 2000 to 4000 DKR
- ☐ 4000 to 6000 DKR
- ☐ 6000 to 8000 DKR
- ☐ 8000 to 10.000 DKR
- ☐ More than 10.000 DKR

41. Do you generally buy new or used products for yourself and your home?

- ☐ I always or almost always buy used stuff
- ☐ I most frequently buy used stuff
- ☐ Both, varies a lot whether I buy used or new stuff
- ☐ I most frequently buy new stuff
- ☐ I always or almost always buy new stuff

42. Do you generally buy cheap products (e.g. discount furniture) or expensive things (e.g. designer clothes) for yourself and your home?

- ☐ I always or almost always buy relatively cheap stuff
- ☐ I most frequently buy relatively cheap stuff
- ☐ Both, varies a lot whether I buy the cheapest or most expensive stuff
- ☐ I most frequently buy relatively expensive things
- ☐ I always or almost always buy relatively expensive things

43. How much do you spend on average on experiences / services per month?

Experiences include, for example, cinema and theater visits, membership of a sports club, restaurants and cafés etc., but not travel.

- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1000 DKR
- ☐ 1000 to 2000 DKR
- ☐ 2000 to 4000 DKR
- ☐ 4000 to 6000 DKR
- ☐ 6000 to 8000 DKR
- ☐ 8000 to 10.000 DKR
- ☐ More than 10.000 DKR

44. How much money have you spent on experiences / services the last 14 days?

- ☐ Less than 250 DKR
- ☐ 250 to 500 DKR
- ☐ 500 to 1000 DKR
- ☐ 1000 to 2000 DKR
- ☐ 2000 to 4000 DKR
- ☐ 4000 to 6000 DKR
- ☐ 6000 to 8000 DKR
- ☐ 8000 to 10.000 DKR
- ☐ More than 10.000 DKR

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Environmental Activities

45. Please indicate how frequently or infrequently you currently do each of the activities listed below.

	Never / almost never	¼ of the time	½ of the time	¾ of the time	Always / almost always
Recycle non-deposit glass jars and bottles					
Recycle newspapers and paper					
Recycle used batteries					
Return drug residues to the pharmacy, instead of throwing them out					
Turn off lights when not in use					
Minimize the amount of water I use					

Personal-Metabolism (PM) coupled with Life Cycle Assessment (LCA) Model: Danish Case Study

Supplementary Information II#

Resource Consumption:
Data Collection and Processing

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1. Introduction

This Supplementary Information (SI) is prepared to present further background information regarding the data work done and data set collected in relation to the work presented in the present paper. The SI II is part of the Ph.D. work of third author Nygaard from Psychological Institute, Aarhus University. The overall PhD project investigates how it is possible to attain a high degree of subjective wellbeing and at the same time have a (relatively) sustainable use of natural resources. The purpose of the PhD project is to find out how we can live good lives without destroying the earth, which we need for long time thriving. One of the ways we investigate this is to identify a best practice group, i.e. people who live with a relatively high degree of wellbeing and a relatively low degree of resource use.

Measuring wellbeing in relation to environmental sustainability required devising a method for measuring environmental sustainability across a large sample population, taking into account all aspects of human consumption.

The present report contains an account of how data was collected, cleansed and processed to enable the analysis of environmental sustainability of individual resource consumption patterns. The workflow diagram in Figure S1.1 provides an overview of the activities conducted in collecting, cleansing and processing the data used in the present investigation.

This supplementary information was prepared by Simon Elsborg Nygaard and Simon Kabins

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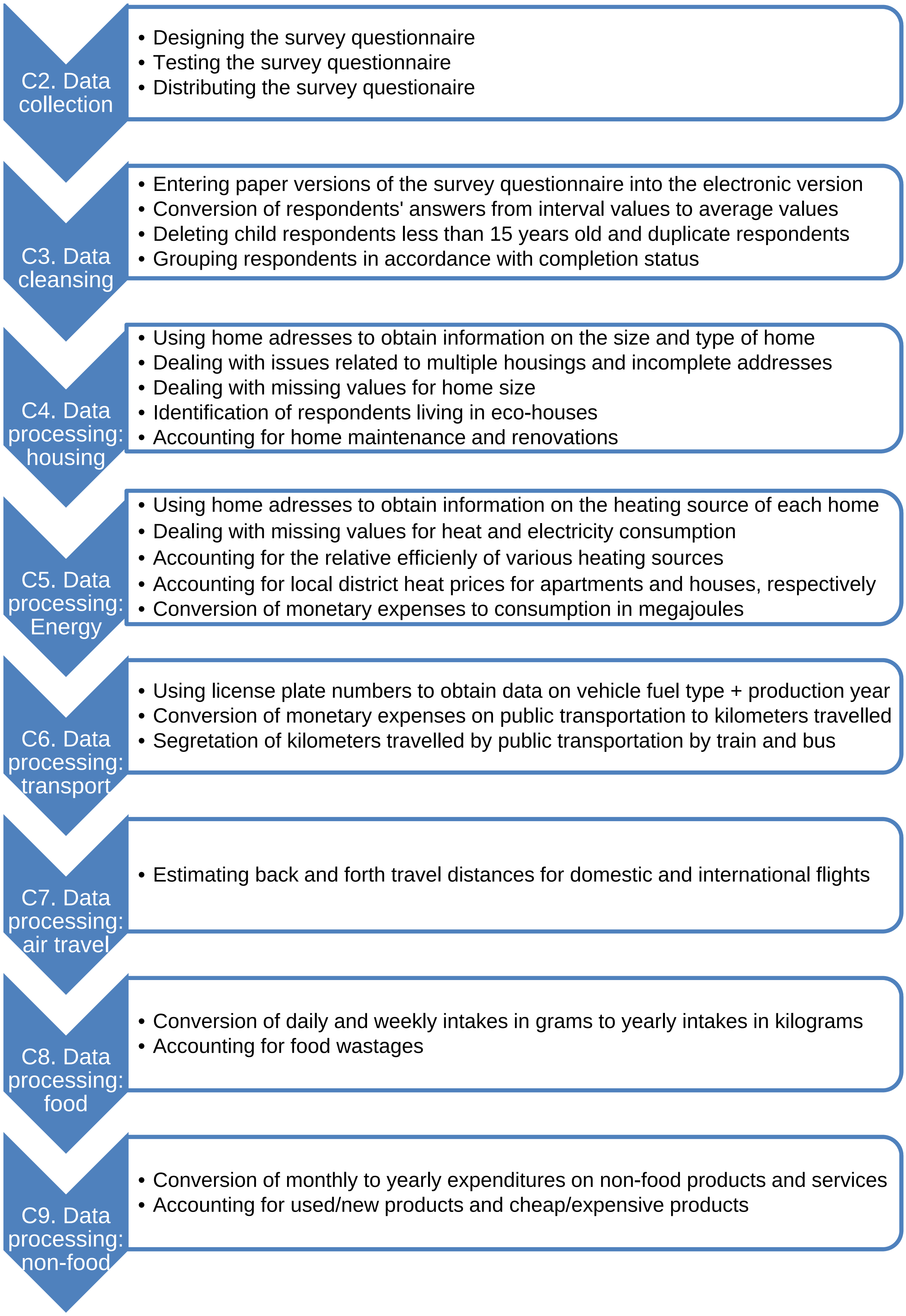
Each of the sequential steps in Figure S1.1 has a corresponding chapter in this report outlining in detail how the listed activities were conducted. Chapter 2 contains an account of the data collection phase lasting approximately 10 months (from January to October 2014). This includes the choice to use an internet survey questionnaire for collecting data, and how the survey questionnaire was designed, tested and distributed. Chapter 3 then goes on to describe how the collected data was cleansed. This involved, among other things, grouping respondents in accordance to the number of questionnaire sections that they had completed.

Finally, Chapters 4-9 contain an account of how the collected data on each respondent's resource consumption was processed to enable the analysis of environmental impacts for each consumption category. This was done from November 2014 to May 2015.

Figure S1.1. Overview of the activities conducted in collecting and processing the data.



2. Data Collection

The present chapter contains an account of the choice to use an Internet survey questionnaire for collecting data, and how the questionnaire was designed, tested and distributed.

2.1 Data Collection Method: Internet Survey Questionnaire

One of the research objectives of the overall investigation was to identify a best practice group of individuals that were able to combine high levels of happiness and environmental sustainability. This, however, required a relatively large sample population to increase the likelihood that the identified group of best practice individuals also constitutes best practice for the whole country. Estimating environmental sustainability further required a considerable amount of information on the individual consumption patterns of each participant.

We decided that an Internet survey questionnaire would constitute the most suited data collection method for balancing these concerns, as it can both be distributed to many individuals at a very low cost, while at the same time allowing for the collection of relatively rich data from each respondent.

2.2 Designing the Overall Survey Questionnaire

Our primary concern in designing the survey questionnaire was to balance the need for collecting rich data from each respondent with the need to keep the questionnaire as short as possible (to reduce the risk of respondents not completing the questionnaire). In the end, we decided to operate with a questionnaire comprising a total of 148 questions and taking 30-60 minutes to answer. In retrospective, this seemed to be well balanced, as we gained enough information to answer our research questions and 1208 respondents answered the full questionnaire.

2.3 Designing the Questionnaire Sections on Resource Consumption

The following elaborates on the consumption items covered in the questionnaire and how questions and measurement units for each consumption item were defined.

2.3.1 Choosing the Consumption Items to Cover in the Questionnaire

In choosing the most important consumption items to cover in the questionnaire we were foremost inspired by the two reports by Chrintz (2010; 2012) along with various Internet sources, including carbon footprint calculators. Furthermore we consulted different kinds of experts, hereunder Chief Knowledge Officer at the Green Danish think tank CONCITO, Torben Chrintz, and Chair of the Danish Association of Eco Societies, Ditlev Nissen.

Based on this investigation we chose to operate with six categories for human consumption: Housing, Energy (electricity, heat), Road Transportation, Air Travel, Food, and Non-food

Products & Services. While Energy, Road Transportation, and Air Travel include relatively few individual consumption items (i.e. heat, electricity, vehicles, and fuel), the Housing, Food, and Non-food categories each comprise a close to endless list of individual products and services. For the latter three categories it was, therefore, especially necessary to make a number of simplifications.

In regards to Housing, various construction materials (e.g. wood, bricks, concrete, glass etc.) are used in different quantities and combinations to build, maintain, and renovate houses, townhouses, apartments etc. Accounting for the specific quantities and combination of construction materials used to build and maintain a particular housing is close to impossible. Therefore, it was assumed that all housings are made from the same combination of construction materials. This allowed us to estimate the quantity of construction materials used for building, maintaining, and renovating a standard housing simply in terms of the size of the housing and total renovation expenditures.

For food, the food items generally considered to have the highest impact on the environment were covered in the questionnaire – more specifically meat, milk, and cheese products (cf. Jones, Kammen, & McGrath, 2008). We did, however, also include legumes, as these are commonly used as a replacement for meat in vegetarian or vegan diets. For all remaining low impact food items, such as vegetables and fruits, average consumption values for men and women, respectively, were referred from a comprehensive study of food consumption in Denmark for the period 2011-2013, reported in Pedersen et al. 2015.

Finally, for the non-food category we decided to operate with three broad subcategories: home products (e.g. televisions, furniture, gardening tools etc.); personal products (e.g. cell phones, cosmetics, clothes etc.), and services (e.g. cinema and theater visits, hotels, restaurants etc.). It was thus assumed that the mix of particular products and services in each category was the same for each respondent.

Table S2.2 provides an overview of the various consumption items covered in the questionnaire section on *Resource Consumption*. The next section contains an account of how questions were phrased and measurement units defined to cover the consumption items listed in Table S2.2.

Table S2.2. Overview of the consumption items covered in the questionnaire.

Category	Consumption items covered in the survey questionnaire
Housing	Construction materials for building housings Construction materials for maintenance and renovations Craftsman services for building and renovating housings
Energy	Heat consumption Electricity consumption
Road Transportation	Vehicles (cars, sharing-cars, motorbikes, scooters) Fuel consumption due to transportation by private car Fuel consumption due to public transportation by bus and train
Air Travel	Fuel consumption due to transportation by airplane
Food	Intake of beef Intake of pork Intake of poultry Intake of seafood Intake of eggs Intake of legumes Intake of milk products Intake of cheese products Food waste
Non-food Products and Services	Personal products (e.g. cell phones, cosmetics, clothes, etc.) Home products (e.g. televisions, furniture, gardening tools, etc.) Services (e.g. cinema and theater visits, hotels, restaurants, etc.)

2.3.2 Defining Questions and Measurement Units for Each Consumption Item

In defining questions and measurement units for each consumption item covered in the questionnaire our main focus was on making questions as relevant and easy as possible for respondents to answer.

In regards to the relevance of questions, activation rules were used to ensure that the respondent was not presented with irrelevant questions. Activation rules refer to a function in SurveyXact, where irrelevant questions in the electronic questionnaire will automatically be left out. For example, if the respondent had indicated that he/she is vegetarian, then the respondent was not presented with the questions for meat consumption. If the respondent was unemployed, then he/she was not asked to provide information on the distance to work, etc.

In regard to easiness the consumption measurement units used in the analysis of environmental impacts (e.g. heat consumption in mega joules) do not match the measurement units used in most people's everyday life (e.g. monetary heat expenditures).

For example, we needed information on the size and type of the respondent's home, in order to estimate the amount of construction materials used to build the home. We also needed information on the type of housing (i.e. house or apartment), the heating source (e.g. district heat, natural gas, heating oil, etc.), and zip code of the respondent, in order to convert heat expenditures into heat consumption in mega joules.

Instead of providing this information, respondents were asked simply for their home address, which was then used to manually access detailed information on each home in the Danish Construction and Housing Register.

Another important consideration for us in making the questionnaire as easy as possible was to avoid questions requiring the respondent to process several pieces of information per question. For example, while we did not care whether the meat consumed by respondents was hot or cold, we chose to operate with two separate questions for hot and cold meat, respectively, for each type of meat. This choice was made, as we deemed it more likely that respondents would be able to give more precise estimates of their meat consumption, if considering intake of hot meals with meat and meals with cold cuts separately – rather than having respondents to add the intake of cold and hot meat up. The obvious drawback of reducing the complexity of questions in this way was a longer questionnaire.

Finally, a basic approach taken in the questionnaire was not to ask for exact consumption values, as this was deemed too difficult for respondents to provide. Instead, single choice questions were used asking respondents to choose from a range of interval values (e.g. 500-1000) that were subsequently converted to average values (e.g. 750) as part of cleansing the data. In defining answer choice options for each question we had to balance several concerns. We needed to have fine grained options for the lower end of the consumption scale, in order to be fully able to capture best practice. But we also wanted to keep choice options for the remaining respondents relatively nuanced. Consequently, the number of answer choice options for each question was generally rich.

2.4 Testing the Survey Questionnaire

A first draft version of the questionnaire was carefully reviewed and tested before final distribution. The psychological sections of the questionnaire were reviewed by psychologists at Aarhus University, whereas the section on Resource Consumption was reviewed by Torben Chrintz, Chief Knowledge Officer at the Danish think tank CONCITO. Furthermore people in our network answered the questionnaire to give feedback.

A modified version of the questionnaire was tested on 52 students at a Danish folk high school ("Højskole"). In this version the questions for housing and energy had been removed, since students live as a collective at the school (and thus have an equal amount of space available, as well as equal expenditures on heat and electricity). Upon completing the questionnaire some of the students were interviewed (while the questionnaire was still fresh in mind) and asked to be as critical as possible. This led to several improvements, foremost in how questions were presented.

Finally, having incorporated the students' suggestions for improvement, the full version of the questionnaire was tested on groups of pilot persons from our network and people related to our collaboration partners, for example TransitionNow (OmstillingNu) or Agenda Center Albertslund.

The general evaluation was, that even though people perceived the questionnaire as quite long, the questions were wellput, understandable and possible to answer, and only small improvements were made at this stage.

On the basis of these three pilot tests, we therefore concluded, that the questionnaire was ready to distribute.

2.5 Distributing the Survey Questionnaire

In distributing the survey questionnaire we collaborated with a number of partner organizations and networks, including Agenda Center Albertslund, Transition Town Ry, Association of Danish Ecovillages, Danish Vegetarian Society, SustaIN, and OmstillingNu. Without these collaborations it would not have been possible to collect the amount of data we did. For example, Albertslund Agenda Center handed out a flyer containing a link to the survey questionnaire to all households (approximately 12,500) in Albertslund Municipality (zip codes 2600 and 2620). The same flyer was also distributed to all households (approximately 3,500) in the town of Ry (zip code 8680) with great help from Transition Town Ry. 60% of the respondents in the sample were from either Albertslund or Ry.

The electronic survey questionnaire was opened for responses on June 20th and closed on October 13th 2014. When the survey was closed a total of 1216 respondents had completed the questionnaire, whereas 978 had partially completed, and 1035 had clicked the distributed link to the questionnaire. In Chapters 3 and 4-9 it is further elaborated how the data for these respondents was subsequently cleansed and processed.

3. Data Cleansing

As mentioned in Chapter 2, making the questionnaire section on *Resource Consumption* more digestible to respondents entailed asking “indirectly” for the information we needed for the analysis of environmental impacts (e.g. monetary heat and electricity expenses instead of consumption in kWh or mega joule). Consequently, extensive subsequent data processing was needed.

The present chapter focuses on this data processing conducted for the questionnaire as a whole. In Chapters 4-9 the data processing conducted specifically in relation to the questionnaire section on *Resource Consumption* is described in detail for each of the consumption categories Housing, Heat & Electricity, Road Transportation, Air Travel, Food, and Non-Food Products & Services.

3.1 Entering Paper Versions of the Questionnaire

16 respondents had answered the paper version of the questionnaire. These were written into the electronic version of the questionnaire. Probably because it was not possible to use validation rules in the paper version, all of the 16 respondents had skipped some of the questions. Therefore, only the answers provided *before* skipping a question were considered for these respondents (as to they would not have been able to complete the electronic version of the questionnaire without answering all questions). Thus, the 16 respondents were added to the partially completed group, now comprising a total of 994 respondents.

3.2 Deleting Child Respondents and Duplicate Respondents

As the investigation considers only adults (defined to be 15 years old or more), respondents less than 15 years old (i.e. born after 1999) were deleted.

Duplicate respondents (i.e. respondents that had completed or partially completed the questionnaire twice or more) were also deleted. These were identified by cross-referencing the following information provided by respondents:

- Gender
- Age
- Address
- Phone number (if provided)
- Email (if provided)

In deleting duplicate respondents the following analytical rules were applied:

✓ If a respondent with the same gender, age, and address has completed one questionnaire and partially completed one or more questionnaires,

➢ then the partially complete questionnaire(s) are deleted.

- ✓ If a respondent with the same gender, age, and address has partially completed two or more questionnaires,
- ➢ then the least completed version(s) are deleted.

- ✓ If a respondent with the same gender, age, address, and email and/or phone number has completed two or more questionnaires,
- ➢ then the questionnaire(s) that were first answered (i.e. with the oldest date of completion) are deleted.

From Table S3.1 it is apparent that a total of 11 respondents less than 15 years old, and a total of 49 duplicate respondents were deleted from the sample, thus reducing the complete and partially complete groups to 1204 and 946 respondents, respectively.

Table S3.1. Number of child respondents and duplicate respondents deleted.

	Complete	Partially complete
Number of respondents before deletion	1216	994
Respondents less than 15 years old (deleted)	1	10
Duplicate respondents (deleted)	11	38
Number of respondents after deletion	1204	946

3.3 Grouping Respondents in the Partially Complete Group

Finally, respondents in the partially complete group were sorted in subgroups in accordance to the sections of the questionnaire that they had completed. From Table S3.2, listing the sections of the questionnaire in chronological order, it is apparent that 647 of the 946 respondents in the partially complete group had completed the *Demographics* section. 503 of these respondents had also completed the *Sustainable Actions* section. Most of the respondents (424 in total) have quit the questionnaire when answering the questions concerning *Ressource Consumption*, and only 79 respondents in the partially complete group had thus completed this section. This is probably because the *Resource Consumption* section was extensive, comprising several subsections for each consumption category.

From Table S3.2 it is also apparent that 7 respondents had completed all questionnaire sections, with three of them only missing to provide the date of completion and four only missing to press the “Finish” button at the end of the questionnaire.

Table S3.2. Grouping of respondents based on completion status and total sample sizes used.

Sections completed	Partially complete group	Total sample size
No sections completed	299	-
Demographics	647	1851
Sustainable Actions	503	1707
Ressource Consumption	79	1283
Happiness	57	1261
Psychological Needs	37	1241
Personal Values	19	1223
Life Quality and Sustainability	7	1211
Date of completion / all sections	4	1208

In Table S3.2 the column “Total sample size” provides an overview of the various sample sizes used in the separate analyses comprising this research. For example, when analyzing (only) the relationship between *Demographics* and *Sustainable Actions* a sample size of (1204 + 503 =) 1707 respondents is used. When analyzing (only) the relationship between *Resource Consumption* and *Demographics* and/or *Sustainable Actions* a sample size of (1204 + 79 =) 1283 respondents is used, and so forth. Thus, the maximum sample size is 1707, and the minimum sample size is 1211.

The present report deals only with the sample of 1283 respondents completing the questionnaire section on resource consumption.

4. Data Processing: Housing

4.1 Collected Data on Housing

In the questionnaire, respondents were asked to provide information on: 1) the number of adult and child residents in their respective households; 2) the year they moved into the home; 3) the amount of expenditure on maintenance and renovations, and; 4) the address of their primary home and, if they owned a vacation house, their secondary home.

Addresses were asked for, as we deemed it likely, that this would give more precise data about housing and save some time for the respondents. Using the address provided, the home of each respondent was looked up in the Danish Construction and Housing Register providing a rich source of information on each home in Denmark, including information on the size of the home (in square meters), the type of home (e.g. house, apartment etc.), and year of construction.

For our present purposes, the following information from the Danish Construction and Housing Register was collected based on the addresses provided by the respondents:

- Size of the respondent's primary home and vacation home in square meters
- Type of the respondent's primary home, e.g. house, apartment etc.
- Heating source, e.g. district heat, natural gas, wood etc.

For the present analysis only the size of the respondent's primary home and vacation home was used, whereas the information on the type of home and the heating source was used in the analysis of heat consumption (see Chapter 5). Typing this data into the dataset provided a way of gaining exact data on each respondent's home.

4.2 Processing the Data on Housing

Arguably, using the addresses of respondents to collect information from the Danish Construction and Housing Register provided the best approach in collecting the most objective data possible on housing and making it easy and save time for respondents. However, for a total of 109 respondents, the approach required some degree of interpretation of the data to deal with various issues related to multiple housings and incomplete addresses, missing values, and housings in Danish eco-villages. These issues and how they were dealt with are described in the following sections.

4.2.1 Issues Related to Multiple Housings and Incomplete Addresses

Two respondents in the sample had provided the same address for both the primary home and the vacation home. In these cases, the following analytical rule was used:

If a respondent has entered the same address for both the primary home and the vacation home, then the respondent is considered only to have a primary home.

7 respondents in the sample had provided addresses that include both a home residence and a commercial building (“Blandet bolig og erhverv”). In these cases, the following analytical rule was used:

- ✓ If an address includes both a home residence and a commercial building,
- ➢ then only the home residence is considered in the analysis.

3 respondents in the sample lived in dorms, but had only provided the road number, but not the apartment number. In these cases, the following analytical rule was used:

- ✓ If the dorm apartment number is unknown,
- ➢ then the size of the apartment is estimated as the average size of all apartments in the building (“Gns.kollegie.nr”).

4 respondents in the sample lived in apartments, but had only provided the road number and floor number, but not the floor side. In these cases, the following analytical rule was used:

- ✓ If the floor side of the apartment is unknown,
- ➢ then the size of the apartment is estimated as the average size of all apartments on the floor (“Gns.lejlighed.etage”).

36 respondents in the sample lived in apartments, but had only provided the road number, but not the floor number and side. In these cases, the following analytical rule was used:

- ✓ If the floor number and side of the apartment are unknown,
- ➢ then the size of the apartment is estimated as the average size of all apartments with the same road number (“Gns.lejlighed.opgang”).

9 respondents in the sample lived in houses, townhouses or farmhouses where the road number also included a letter that had not been provided by the respondents. In these cases, the following analytical rule was used:

- ✓ If the road number is not unique, and the letter being part of the road number is unknown,
- ➢ then the size of the house is estimated as the average size of all houses with the same road number (“Gns.parcelhus”, “Gns.rækkehus”, “Gns.stuehus”).

4.2.2 Dealing with Missing Values for Home Size

50 of the addresses provided for primary homes and forty-one of the addresses provided for vacation homes could not be looked up in the Danish Construction and Housing Register. In these cases, missing values for the home size per person was filled using arithmetic mean values of the rest of the respondents in the sample (53.79 m^2 for primary homes and 37.52 m^2 for vacation homes).

4.2.3 Identification of Respondents Living in Ecovillages

In some Danish ecovillages, houses are constructed with reused construction materials and/or environmentally friendly materials, such as hay. Such houses have a considerably lower impact than the average Danish standard house made from (new) bricks and mortar.

The respondents living in eco-houses were identified as follows. First, a list of all registered ecovillages in Denmark was obtained from The National Association for Ecovillages. Futhermore. Other sources like eco village expert, magazines and the Internet was searched. Then, the website of each ecovillage was visited to identify the ecovillages where environmentally friendly building is part of the mission statement (some ecovillages focus only on food production). Next, Google Maps was used to identify all roads in each ecovillage. Finally, a search for each identified road name was conducted in the addresses provided by the respondents. Using this approach, 76 respondents living in ecovillages were identified.

4.3 Estimating the Housing Area Occupied by Each Respondent

The number of square meters occupied by each individual respondent was calculated by dividing the size of the respondent's primary home and vacation home with the number of residents in the household. From Table S4.1 it is apparent that the average home size per household/person is slightly larger for primary homes and approximately ten percent larger for vacation homes in the sample than for the rest of Denmark.

Table S4.1. Housing area occupied by households and individual respondents in the sample.

	Primary home		Vacation home	
	Sample	Denmark*	Sample	Denmark**
Average home size per household	112.66 m^2	111.60 m^2	81.28 m^2	71.33 m^2
Average home size per person	53.79 m^2	52.10 m^2	37.52 m^2	33.26 m^2

* Source: Statistics Denmark, *Denmark in Figures 2015*, p. 7.

** Source: Statistics Denmark (BYGB12 and BYGB34 databases).

4.3.1 Accounting for Maintenance and Renovations

Next, new materials procured and used for maintenance and renovation of homes were accounted for by asking respondents to provide information on the total amount of expenditure on maintenance and renovation (for primary homes only). In addition, respondents were asked to assess the extent to which the renovations had been made by hired craftsmen or themselves. The purpose of the latter question was to assess the percentage of expenditure spent of construction materials and labor, respectively, by each respondent. The reason is, that while the production of construction materials, particularly concrete, exert a considerable environmental impact, the impact of labor per se is close to zero.

Assuming that renovations made by hired craftsmen cost twice the amount of do-it-yourself renovations (i.e. the costs of construction materials and labor costs are evenly distributed) the expenditure indicated by each respondent was factorized to take into account only the expenditure on construction materials, as shown in Table S4.2.

Table S4.2. Assessing labor costs and expenditure on construction materials.

Percentage of renovations made by craftsmen	100%	75%	50%	25%	0%
Percentage of expenditure spent on construction materials	50.0%	62.5%	75.0%	87.5%	100%
Number of respondents that have renovated their home (n=719)	194	137	137	120	131
Average total expenditure on renovations (DKK)	276,869	279,088	250,584	130,083	97,786
Average expenditure on hired craftsmen (labor costs) (DKK)	138,434	104,658	62,646	16,260	0
Average expenditure on construction materials (DKK)	138,434	174,430	187,938	113,823	97,786

Having estimated the expenditure on construction materials for each respondent, this amount was then converted to an equivalent standard house area, using a standard construction cost of 13608 DKK/m^2 (Dol and Haffner, 2010). The equivalent area was then divided by the number of residents and added to the standard house area per person used to finally estimate the environmental footprint of housing, as shown in Table S4.3.

Table S4.3. Equivalent standard house area per household and individual respondent.

	Primary home	Vacation home
Average expenditure on construction materials per household (renovation and maintenance)	80,257 DKK	-
Average expenditure on construction materials per individual respondent (renovation and maintenance)	34,969 DKK	-
Average equivalent standard house area per household (renovation and maintenance)	5.90 m^2	-
Average equivalent standard house area per individual respondent (renovation and maintenance)	2.57 m^2	-
Average number of square meters per individual respondent	53.79 m^2	37.52 m^2
Average total number of square meters per individual respondent (used for further analysis)	*56.36 m^2*	*37.52 m^2*

5. Data Processing: Heat & Electricity

5.1 Collected Data on Heat and Electricity Consumption

In the questionnaire, respondents were asked to provide information on the amount of expenditure for heat and electricity, respectively. For both heat and electricity, respondents were also given the option to write a comment. Only heat and electricity consumption in primary homes was considered. Respondents were instructed to ignore energy consumption in vacation homes, foremost because many vacation home owners in Denmark rent out the vacation home when they do not use it themselves. In these cases, heat and electricity is also consumed by tenants and should thus not be single-handedly attributed to the vacation home owner.

As mentioned in the previous chapter, data on the type of housing and heating source was also collected from the Danish Construction and Housing Register using the address provided by each respondent. For the purpose of the present analysis housing types were grouped in a “house” category (houses, farmhouses, townhouses, vacation homes, other) and an “apartment” category (apartments, dorms, residential institutions).

In terms of the heating source the following categories (relevant for the sample of respondents) are:

- District heat
- Electricity
- Liquid fuel (heating oil, petrol, bottled gas)
- Solid fuel (coal, coke, wood)
- Straw
- Natural gas

For the categories liquid fuel and solid fuel the exact type of fuel used in a particular housing is not specified in the Danish Construction and Housing Register. Therefore, in typing in the data on the heating source these categories were assumed to comprise only heating oil and wood, respectively.

The following sections contain a detailed account of how the above data were further processed and used to estimate heat and electricity consumption for each respondent.

5.2 Processing the Data on Heat and Electricity

Processing the data on heat and electricity entailed first dealing with missing values for heat and/or electricity expenditures. Second, since monetary expenditures were asked for in the questionnaire as to make answering easier, it was necessary to account for variations in the price and efficiency of the above listed heating sources. Third, since the price of district heat varies considerably from heating plant to heating plant (more than 100 percent) and also depends on the housing type, it was also necessary to account for local district heat prices for houses and apartments, respectively.

5.2.1 Dealing with Missing Values for Heat and Electricity Expenditures

From the answers provided it was apparent that 90 respondents had answered “0” for heat expenditure, whereas 85 respondents had answered “0” for electricity expenditure (see Table S5.1 below). 64 of these respondents were identical (i.e. had answered “0” for both heat and electricity).

These numbers were surprisingly high, considering that a normal Danish/western lifestyle cannot be combined with zero energy consumption, unless people are able to self-produce the energy they use. Therefore, comments provided by respondents answering “0” for heat and/or electricity expenditure were reviewed.

From this review it was apparent that 82 of the 90 respondents answering “0” for heat and 74 of the 85 respondents answering “0” for electricity had written a comment. In 20 of the comments for heat respondents had written that they use electricity for heating (i.e. the heating bill is included in the electricity bill), or some alternative energy source, such as solar power or geothermal heat. In 15 of the comments for electricity respondents had written that they have solar panels. For these respondents, as well as for the respondents providing no comments, the value of 0 was considered to represent the actual consumption of the respondent.

Table S5.1. Review of the comments provided by respondents on heat and electricity.

	Heat	Electricity	Both	Total
Number of respondents answering “0” for heat and/or electricity expenditure	90	85	64	111
Number of respondents answering “0” and writing a comment	82	74	56	100
Number of respondents answering “0” and writing “do not know” in the comment	62	61	54	69

In 62 and 61 of the above comments for heat and electricity, respectively, respondents had written “do not know” (“ved ikke”), “no idea” (“ingen idé”), or some similar (Danish) expression clearly indicating that the “0” represented a missing “do not know” option. 54 of these respondents were identical (i.e. had answered “0” for both heat and electricity and commented on both consumption items).

In designing the questionnaire we deliberately chose *not* to include a “do not know” option in the single choice questions for heat and electricity, in order to force respondents to provide an answer.

For the 62 (4.83%) and the 61 (4.75%) respondents writing a comment indicating that the “0” represented a “do not know” the 0 value was considered to represent a missing value. Missing values for heat and electricity were filled using arithmetic mean values of the rest of the respondents in the sample (see Table S5.2). For respondents where the housing size and type was known (see Chapter 4) the average heat and electricity expenditures per square meter for houses and apartments, respectively, was multiplied with the size of each respondent’s home. For respondents where the housing size and type were also missing average yearly heat and electricity expenditures were used.

Table S5.2. Average heating and electricity expenditures of respondents in the sample.

	Houses	Apartments
Average heating expenditure per square meter (DKK/m^2/year)	87.80	68.79
Average electricity expenditure per square meter (DKK/m^2/year)	53.71	56.75
Average yearly heating expenditure (DKK/year)	11007.51	
Average yearly electricity expenditure (DKK/year)	5550.78	

5.2.2 Accounting for Various Heating Sources (Non District Heat)

While the respondents in the sample use different heating sources, it was only possible to account for district heat in the subsequent Life Cycle Analysis of environmental impacts. Moreover, various heating sources vary in terms of their price and efficiency, and thus the amount of energy that can be purchased and consumed for the same amount of money varies from heating source to heating source. Since respondents had provided information on their heat consumption in terms of heat expenditures (to make the question easier to answer) it was, therefore, possible to account for variations in the price and efficiency of various heating sources.

In Table S5.3 the number and percentage of respondents using various heating sources are listed. In the left column the raw data extracted from the Danish Construction and Housing Register is shown, whereas the right column shows how the data was modified. For the 50 respondents with addresses that could not be looked up in the Danish Construction and Housing Register the heating source was assumed to be district heat, as this is the most common source of heating. For 11 respondents (using natural gas, heating oil, or wood) with missing values for heat expenditure the estimated heat expenditure was also considered in terms of district heat. Finally, since it was not possible to collect good data on the average price of straw, the 5 respondents using straw as heating source were considered part of the wood category.

Table S5.3. Number and percentage of respondents using various heating sources.

	Raw data (DCHR)		Modified	
	Respondents	Percentage	Respondents	Percentage
District heat	976	76.07%	1037	80.83%
Natural gas	72	5.61%	67	5.22%
Heating oil	55	4.29%	52	4.05%
Wood	63	4.91%	65	5.07%
Straw	5	0.39%	-	-
Electricity	62	4.83%	62	4.83%
Unknown	50	3.90%	-	-
Total	1283	100%	1283	100%

For the 62 respondents with electricity as heating source heating expenditures were simply added to the electricity expenditures, and thus, heating was modelled as part of electricity in the subsequent Life Cycle Analysis of environmental impacts.

For the 184 respondents with natural gas, heating oil, or wood as heating source the conversion rates shown in Table S5.4 were used to calculate how many mega joules of energy it was possible to purchase for the amount of money provided by the respondent.

Table S5.4. Rates used to convert heat expenditures to energy consumption in mega joules.

	DKK/amount*	MJ/amount**	DKK/MJ
Natural gas	8.81 DKK/m^3	36.00 MJ/m^3	0.3685 DKK/MJ
Heating oil	11.94 DKK/liter	32.40 MJ/liter	0.2447 DKK/MJ
Wood	2.45 DKK/kilo	14.04 MJ/kilo	0.1748 DKK/MJ

* Sources: Danish Energy Regulatory Authority, Danish Oil Industry Association (EOF), and a large Danish supplier of wood to average consumers.

** Source: Danish Energy Regulatory Authority.

5.2.3 District Heat: Accounting for Local Price Variations

District heating systems use the heat from various energy sources, such as combined heat and power plants / cogeneration (CHP), surplus heat from the industry, large solar thermal systems, geothermal heat, and large-scale heat pumps (DBDH, 2015). Since district heating plants in Denmark produce heat in different ways, local prices vary considerably (more than a 100 percent). Moreover, prices are (to a lesser extent) also determined by the type of housing (i.e. house or apartment).

Therefore, in converting the yearly heating expenditures provided by respondents in the questionnaire to yearly heat consumption in mega joules it was necessary to account for local price variations for houses and apartments, respectively. For this purpose, the district heating price statistics provided by the Danish Energy Regulatory Authority for December 2013 (respondents were asked to provide heat expenditures for the year 2013) were used. The price statistics include estimates of the yearly expenditures for heating a "standard house" (yearly energy consumption: 18.1 mWh) and a standard apartment (yearly energy consumption: 15 mWh), respectively, for each heating plant in Denmark. Based on these estimates the average price per mega joule for houses and apartments, respectively, was calculated for each heating plant in Denmark and applied to the respondents.

Finally, one or more heating plant(s) were ascribed to each respondent using the zip codes of the heating plant(s) and the respondent, respectively. In this regard, the following analytical rules were applied:

- ✓ If the zip code of the respondent and the zip code of the heating plant are identical,
- ➢ then the heating is ascribed to the respondent, except for cases were the respondent zip code is in Copenhagen or Aarhus (the far majority of residents in these cities have the same supplier, but both cities have several zip codes).

- ✓ If there are two or more heating plants with the same zip code,
- ➢ then the average price of these heating plants combined is used.

- ✓ If there is not a heating plant with the same zip code as the respondent,
- ➢ then the heating plant with the closest zip code (numerical value) is ascribed to the respondent.

- ✓ If there is not a heating plant with the same zip code as the respondent,
- ✓ and there are two or more heating plants that are equally close to the respondent in terms of the numerical value of zip codes,
- ➢ then the average price of these heating plants combined is used.

5.3 Estimating Heat and Electricity Consumption

The yearly amount of mega joules consumed by each household with district heat was calculated by multiplying the yearly heating expenditure provided by the respondent with the price per mega joule for the particular heating plant(s) ascribed to the respondent, taking into account the respondent's type of housing (i.e. house or apartment). For households with no district heat the yearly heating expenditure provided by the respondent multiplied with the price per mega joule for each heating source shown in Table S5.4.

For electricity an average conversion rate of 0.6125 DKK/MJ was used (derived from the electricity price statistics provided by the Danish Energy Regulatory Authority for December 2013). It should in this regard be mentioned that the price per mega joule is fairly equal across Danish suppliers. Moreover, as opposed to district heating, Danish consumers can freely choose among electricity suppliers, rendering it close to impossible to ascribe specific electricity suppliers to respondents (no geographic relationship).

Next, the yearly amount of mega joules consumed by each individual respondent was calculated by dividing the yearly household consumption in mega joules with the number of people in the household.

The results are presented in Tables 5.5 and 5.6. From Table S5.5 it is apparent that while average yearly heat expenditures vary considerably across heating sources these differences are somewhat modified when expenditures are converted to consumption in mega joules using the conversion rates for each heating source.

From Table S5.6 it is apparent that the average yearly consumptions are considerably lower for electricity than for the heating sources in Table S5.5, due to the fact that the price per mega joule is considerably higher for electricity. It should in this regard be mentioned that while the 62 respondents using electricity for heating have a considerably lower total consumption in mega joules, electricity, on the other hand, has a considerably higher carbon footprint per mega joule than district heat. Therefore, these respondents cannot be assumed to have a lower environmental impact than the other 1221 respondents in the sample, based on the numbers provided in Tables 5.5 and 5.6.

Table S5.5. Heat expenditures and consumption.

	District heat	Natural gas	Heating oil	Wood
Number of respondents	1037	67	52	65
Average yearly expenditure per household (DKK)	8378.44	11716.42	13247.50	7125.00
Average yearly expenditure per individual (DKK)	4245.64	5495.63	5922.83	2939.56
Average yearly consumption per household (MJ)	37487.29	47876.40	35947.99	40760.05
Average yearly consumption per individual (MJ)	19203.14	22456.60	16072.01	16816.37

Table S5.6. Electricity expenditures and consumption.

	Electricity (including heat)	Electricity (ex-cluding heat)	Electricity (all)
Number of respondents	62	1221	1283
Average yearly expenditure per household (DKK)	17364.38	5329.55	5911.13
Average yearly expenditure per individual (DKK)	7632.50	2551.90	2797.41
Average yearly consumption per household (MJ)	28350.01	8701.31	9650.82
Average yearly consumption per individual (MJ)	12461.22	4166.36	4567.21

6. Data Processing: Road Transportation

6.1 Collected Data on Vehicles

In the questionnaire, respondents were asked whether they owned a private car, and if yes, to provide the license plate (registration) number of their primary vehicle, or alternatively, the brand, model, and production year of the vehicle. Similar to addresses for housings, license plate numbers provide access to detailed and exact information on any given vehicle in Denmark in the Danish Register of Motor Vehicles.

When designing the questionnaire it was our intention to use a variety of information on each car to estimate environmental impacts, including weight of the car and mileage per liter of fuel. However, as it turned out, this information could not be used to differentiate the environmental impacts of different cars using the present Ecoinvent 2.2 database in Gabi 6.0. Therefore, only information on the production year and fuel type (i.e. gasoline, diesel, or electric) was used to conduct the analysis of environmental impacts.

Of the 883 car owners in the sample (see Table S6.1), only 384 provided license plate number that could be used to look up information on the vehicle in the Danish Register of Motor Vehicles (see Table S6.2). For the 499 car owners that did not provide a license number – or a false license number – the fuel type could only be determined for sure in 68 cases. In 431 cases it was assumed that the fuel type was gasoline, being the most common fuel type in Denmark (see Table S6.3).

Table S6.1. Households with and without car.

	Sample		Denmark*	
Households with 1 car	656	51.13%	1,303,341	44.69%
Households with 2 cars	172	13.41%	396,308	13.59%
Households with 3 cars	9	0.70%	45,597	1.56%
Households with more than 3 cars	4	0.31%	8,689	0.30%
Households with sharing car only	42	3.27%	-	-
Households with car (total)	*883*	*68.82%*	*1,753,935*	*60.13%*
Households with no car	*400*	*31.18%*	*1,162,742*	*39.87%*
Total	1283	100%	2,916,677	100%

* Source: Statistics Denmark (BIL800 database)

Table S6.2. Determining the fuel type for each car in the sample.

	Sum	%
Number of license plate numbers	400	100%
Number of license plate numbers for diesel cars	127	31.75%
Number of license plate numbers for gasoline cars	257	64.25%
Number of false license plates (fuel type assumed to be gasoline)	16	4.00%
Number of missing license plate numbers	483	100%
Number of respondents indicating that the fuel type is diesel	64	13.25%
Number of electric car models	4	0.83%
Number of cars assumed to be gasoline fueled	415	85.92%
Total number of (primary) cars in the sample	883	100%
Total number of usable license plate numbers	384	43.49%
Total number of missing or false license plate numbers	499	56.51%
Total number of cars assumed to be gasoline driven	431	48.81%

Table S6.3. Distribution of fuel types.

	Sample		Denmark*	
Gasoline cars	688	77.92%	1,623,238	71.26%
Diesel cars	191	21.63%	653.290	28.68%
Electric cars	4	0.45%	1,536	0.07%
Total	883	100%	2,278,064	100%

* Source: Statistics Denmark (BIL10 database)

While the questionnaire displayed weaknesses in terms of gathering data on the fuel type, data on the production year of the vehicle (and/or license plate number) was provided by 858 (97.17%) of the 883 car owners in the sample.

6.2 Collected Data on Road Distances

Respondents were also asked for the number of kilometers travelled by car in the last year. In the analysis of environmental impacts, the road distance travelled by car was then segregated for respective Euro Emission Standards using the data about the production year and the fuel type. From Table S6.4 it is apparent that the average road distance travelled per person in the sample is shorter than for the rest of Denmark. This is not surprising considering that the majority of respondents live in or close to the two biggest cities in Denmark where public transportation is relatively good. From Table S6.4 it is also apparent that the 883 cars owners in the sample travel considerably more by car, not surprisingly, than the respondents with no private car.

Table S6.4. Average road distance travelled.

	Sample	Denmark*
Average road distance travelled per person	9161 km	11269 km
Average road distance travelled by car owners	12627 km	-
Average road distance travelled by respondents with no car	1511 km	-

* Source: Statistics Denmark (PKM1 database and FOLK1 database). The average road distance for Danish citizens has been calculated by taking the estimate for the total number of kilometers travelled by car in Denmark in 2013 (PKM1) and dividing it with the number of Danes that were 15 years or older in 2014 (FOLK1) (respondents had to be at least 15 years old to fill out the questionnaire).

6.3 Collected Data on Public Transportation

Finally, public transportation was also accounted for in the questionnaire by asking respondents for their yearly expenditure on public transportation (2775.95 DKK on average). An average public transportation rate of 2.5 DKK per kilometer was used to convert yearly expenditures into kilometers travelled (1110.38 km on average).

The average public transportation rate was estimated using zone distances and travel prices for the Copenhagen area. The Copenhagen area was chosen, since most respondents in the sample live there, and because travel prices are equal for and covers both transportation by bus and train. The average zone distance in the Copenhagen area was estimated to 6 kilometers using this map of zones and Google Maps. The average price for a two zone ride was estimated in terms of Travel Card ("Rejsekort") prices to 15 DKK, representing a middle price between travelling with a single ride ticket and a periodic card. Thus, the average public transportation rate was estimated as (15 / 6 =) 2,5 DKK/km.

Finally, the kilometers travelled were segregated into public transportation by train and bus, respectively. This was done using numbers from Statistics Denmark for the total distance travelled by bus and train, respectively, in Denmark in 2013, as shown in Table S6.5.

Table S6.5. Public transportation (by train and bus).

	Denmark		Sample
Public transportation by train and bus	13,619,000,000 km.	100,00%	1110.38 km
Public transportation by train	7,076,000,000 km.	51.96%	576.92 km
Public transportation by bus	6,543,000,000 km.	48.04%	533.46 km

* Source: Statistics Denmark (PKM1 database)

7. Data Processing: Air Travel

To estimate impacts of air travel, respondents were asked to list the destinations that they have visited by airplane the last year along with the month of departure. For international flights, Copenhagen Airport (accounting for 90.45 of all international flights from Denmark in 2013) was chosen as the default point of departure. The back and forth distances from Copenhagen Airport to the destinations indicated by respondents was then estimated using http://www.worldatlas.com/travelaids/flight_distance.htm). For domestic flights where the respondent had indicated "Copenhagen" or "Denmark" as the destination, the travel distance between the two most used airports in Denmark for domestic flights (Copenhagen and Aalborg) was used (223 km). Finally, the estimated travel distances were added up to arrive at an aggregated distance travelled for each respondent used in the further analysis of environmental impacts.

As shown in Tables 7.1 and 7.2, 59.70% of the respondents in the sample had flown at least once in the last year, travelling on average 11060 kilometers and flying on average 1.9726 times.

Table S7.1. Number of respondents travelling by airplane in the last year.

	Number and percentage of respondents		Average aggregated flight distance travelled
0 flights in the last year	517	40.30%	0 km
1 flight in the last year	383	29.85%	5444 km
2 flights in the last year	197	15.35%	11426 km
3 flights in the last year	100	7.79%	17902 km
4 flights in the last year	47	3.66%	19664 km
5 flights in the last year	15	1.17%	30130 km
6 flights in the last year	10	0.78%	26348 km
7 flights in the last year	8	0.62%	48879 km
8 flights in the last year	1	0.08%	4632 km
9 flights in the last year	3	0.23%	90045 km
10 flights in the last year	2	0.16%	20290 km
Have flown in the last year	766	59.70%	11060 km
All respondents	1283	100%	6603 km

Table S7.2. Number of flights in the last year.

	Number of flights	Percentage
0-250 km (domestic)	31	2.05%
250-500 km	94	6.22%
500-1000 km	263	17.41%
1000-1500 km	198	13.10%
1500-2000 km	223	14.76%
2000-3000 km	299	19.79%
3000-4000 km	126	8.34%
4000-5000 km	12	0.79%
5000-7500 km	113	7.48%
7500-10000 km	129	8.54%
10000-15000 km	12	0.79%
Over 15000 km	11	0.73%
Total	1511	100%
Number of flights per (flying) respondent	1.9726	-
Number of flights per respondent (all)	1.1777	-

8. Data Processing: Food Consumption

8.1 Collected Data on Food Consumption

Detailed data about food consumption was collected in the questionnaire for the following food categories: meat, eggs, legumes, cheese, and milk products. The choice to delimit the investigation to animal food categories was made to shorten the questionnaire as much as possible. While legumes constitute a relatively low impact food item, they were included, as they constitute a widely used replacement for meat. Data on the average intake of bread, potatoes, vegetables, fruits, fat, sugar, and beverages for Danish men and women, respectively, was referred from Pedersen et al. (2015).

8.1.1 Meat

In relation to meat, respondents were asked if they were vegetarian, and if no, to provide detailed information about their meat consumption for both hot and cold preparations. For hot preparations, respondents were asked for the weekly number of hot meals for each type of meat (beef, pork, poultry, and seafood) along with the quantity of meat consumed in a typical meal. The weekly intake of hot meat was then estimated for each meat type by multiplying the typical quantity with weekly number of meals for each type of meat.

For cold preparations, respondents were asked for their average daily intake of beef/veel/pork cold cuts and poultry/seafood products, respectively. Using only two categories for cold meat, it was in this regard assumed that the intake of beef/veel and pork cold cuts could be evenly ascribed to the beef and pork categories – and similarly for poultry and seafood products.

Next, the weekly and daily intakes of hot and cold beef, pork, poultry, and seafood were converted to yearly intakes in kilograms and added up for each meat type.

8.1.2 Eggs

Respondents were asked for the typical number of eggs consumed in a week. The weekly number of eggs was converted to yearly consumption in kilograms, assuming that an egg weighs on average 60 grams (Ygil, 2013).

8.1.3 Legumes

Respondents were asked for the typical weekly number of meals with legumes (e.g. beans, peas, lentils) along with the quantity of (dried) legumes consumed in a typical meal with legumes. The weekly intake of legumes was estimated by multiplying the typical quantity with typical weekly number of meals, and finally converted to yearly intakes in kilograms.

8.1.4 Milk and Cheese Products

Respondents were asked for their average daily intake of milk products (milk, yogurt, sour milk, sour cream etc.) and cheese products (cheese, cottage cheese, feta etc.), respectively. The daily intakes of milk products and cheese products, respectively was converted to yearly intakes in kilogram.

8.2 Estimating Food Consumption

Table S8.1 provides an overview of the estimated average food consumption of men and women in the sample compared to the estimates of the comprehensive study on food consumption in Denmark by Pedersen et al. (2015). As earlier mentioned, the consumption values for the food categories marked with grey have been referred from this study. It should be noted that while there is a fairly equal distribution of men (48.94%) and women (51.06%) in the study by Pedersen et al. (2015), the distribution in this study was skewed with 34.84% men and 65.16% women. This is, of course, reflected in the average consumption values for all respondents.

8.2.1 Average Food Consumption of Men and Women

From Table S8.1 it is apparent that the average consumption values for men and women in the sample are considerably lower for beef, pork, seafood, and cheese, and considerably higher for poultry and eggs. The average intake of milk is fairly equal in the two studies.

Table S8.1. Average food consumption for men and women.

	Sample*			Denmark**		
	All	Men	Women	All	Men	Women
Beef (kg)	15.56	19.60	13.40	48.91	62.78	36.14
Pork (kg)	12.22	17.42	9.44			
Poultry (kg)	13.66	15.30	12.79	9.49	10.59	8.76
Seafood (kg)	11.39	13.12	10.47	13.51	14.60	12.41
All meat (kg)	*52.83*	*65.44*	*46.10*	*71.91*	*87.97*	*57.31*
Eggs (kg)	11.46	11.78	11.29	8.76	9.49	8.40
Legumes (dried) (kg)***	7.64	6.27	8.37	-	-	-
Milk (kg)	109.04	131.06	97.28	110.96	123.01	99.65
Cheese (kg)	10.61	11.89	9.93	16.06	17.16	14.97
Corn products (kg)	*76.62*	*90.89*	*68.99*	*79.57*	*90.89*	*68.99*
Potatoes (kg)	*30.46*	*43.07*	*23.73*	*33.22*	*43.07*	*23.73*
Vegetables (kg)	*73.28*	*69.72*	*75.19*	*72.64*	*69.72*	*75.19*
Fruits (kg)	*71.53*	*60.59*	*77.38*	*69.35*	*60.59*	*77.38*
Fats (kg)	*14.30*	*17.16*	*12.78*	*14.97*	*17.16*	*12.78*
Sugar (kg)	*13.16*	*13.87*	*12.78*	*13.51*	*13.87*	*12.78*
Beverages (kg)	*811.80*	*839.87*	*796.80*	*817.60*	*839.87*	*796.80*

* Total number of respondents = 1283. Men = 447 (34.84%). Women = 836 (65.16%).

** Source: Pedersen et al. (2015). *Danskernes kostvaner 2011-2013*.

*** Legumes part of vegetable category in Pedersen et al. (2015).

8.2.2 Average Food Consumption of Vegetarians and Non-vegetarians

Aside from the methodological differences in how food consumption was estimated in the present study and the study by Pedersen et al. (2015), a part explanation for the differences in the results could lie in the relatively high percentage of vegetarians in the present study (19.02%). In comparison, a Danish study from 2010 estimated the percentage of vegetarians in Denmark to 3.9% (FDB 2010).

As shown in Table S8.2, the average meat consumption of men and women in the sample increase considerably, when excluding the relatively large group of vegetarians. For eggs, milk, and cheese the increase is less dramatic, as these food items are often part of vegetarian diets. From Table S8.2 it is also apparent that many vegetarians use legumes as a substitute for meat in that the average consumption of legumes is almost four times higher for vegetarians than for non-vegetarians.

Table S8.2. Food consumption for vegetarians and non-vegetarians.

	Vegetarians*			Non-vegetarians**		
	All	Men	Women	All	Men	Women
Beef (kg)	0.00	0.00	0.00	19.22	21.64	17.67
Pork (kg)	0.00	0.00	0.00	15.09	19.23	12.44
Poultry (kg)	0.00	0.00	0.00	16.87	16.89	16.86
Seafood (kg)	0.00	0.00	0.00	14.07	14.48	13.80
All meat (kg)	*0.00*	*0.00*	*0.00*	*65.25*	*72.23*	*60.77*
Eggs (kg)**	8.34	8.39	8.33	12.19	12.13	12.23
Legumes (dried) (kg)***	18.87	18.50	18.94	5.00	5.01	5.00
Milk (kg)	53.10	51.27	53.49	122.18	139.33	111.23
Cheese (kg)	7.34	7.13	7.38	11.38	12.39	10.74

* Vegetarians = 244. Men = 42 (17.21%). Women = 202 (82.79%).

** Non-vegetarians = 1039. Men = 405 (38.98%). Women = 634 (61.02%).

8.2.3 Food Wastages

A behavioral factor about food wastage was also included in the questionnaire by asking for the percentage of food typically being wasted in the household (6.16% on average). Using the percentage indicated by each respondent, the consumption for each food item was factorized to take into account these food wastages. Table S8.3 provides an overview of the average food consumption, including food wastages, for men and women in the sample along with the percentage increase for each food category.

The consumption values shown in Table S8.3 were used in the further analysis of environmental impacts related to food consumption using Simapro 8.0.4 with the Ecoinvent 3.1 database. Although, Ecoinvent 3.1 is the most recent available database, processes to account for impacts related to eggs, legumes, and beverages are not available in this database and hence could not be part of the assessment study of environmental impacts.

Table S8.3. Average food consumption for men and women, including food wastages.

	All	Factor	Men	Factor	Women	Factor
Beef (kg)	16.60	+6.68%	20.87	+6.48%	14.32	+6.87%
Pork (kg)	13.01	+6.46%	18.50	+6.20%	10.07	+6.67%
Poultry (kg)	14.55	+6.52%	16.24	+6.14%	13.65	+6.72%
Seafood (kg)	12.09	+6.15%	13.89	+5.87%	11.13	+6.30%
All meat (kg)	*56.25*	*+6.47%*	*69.50*	*+6.20%*	*49.17*	*+6.66%*
Eggs (kg)**	12.16	+6.18%	+12.45	+5.76%	+12.01	+6.42%
Legumes (dried) (kg)***	8.08	+5.76%	6.62	+5.58%	8.86	+5.85%
Milk (kg)	116.12	+6.49%	139.07	+6.11%	103.84	+6.74%
Cheese (kg)	11.28	+6.31%	12.61	+6.06%	10.57	+6.45%
Corn products (kg)	81.39	+6.23%	95.53	+5.11%	72.65	+5.31%
Potatoes (kg)	32.35	+6.19%	45.27	+5.11%	24.99	+5.31%
Vegetables (kg)	77.88	+6.27%	73.28	+5.11%	79.19	+5.31%
Fruits (kg)	76.03	+6.29%	63.69	+5.11%	81.49	+5.31%
Fats (kg)	15.19	+6.22%	18.03	+5.11%	13.45	+5.31%
Sugar (kg)	13.98	+6.26%	14.58	+5.11%	13.45	+5.31%
Beverages (kg)	862.61	+6.26%	882.77	+5.11%	839.13	+5.31%

9. Data Processing: Non-food Products & Services

Data on the consumption of non-food products and services was also collected in the questionnaire by asking respondents for their average monthly expenditure on personal products (e.g. mobile phones, cosmetics, clothes, golf equipment, etc.), home products (e.g. televisions, furniture, tools, gardening equipment, etc.), and services/experiences (e.g. restaurants and cafées, cinema and theater visits, membership of a sport club etc., but excluding travel). The monthly expenditures were then converted to yearly expenditures.

Table S9.1 provides an overview of the average expenditures for personal products, home products, and services/experiences, respectively, for different income groups in the sample. Not surprisingly, respondents with higher incomes have considerably higher expenditures than respondents with lower incomes.

Table S9.1. Average expenditure for personal products, home products, and services.

Yearly personal income (after tax)	Respondents	Personal products (DKK)	Home products (DKK)	Services/ experiences (DKK)
0 DKK	16	5718.75	4968.75	3375.00
0 to 50,000 DKK	92	5836.86	4092.39	4728.26
50,000 to 100,000 DKK	209	6653.11	3387.56	4708.13
100,000 to 200,000 DKK	215	7109.30	4960.47	5344.19
200,000 to 300,000 DKK	475	7932.63	6360.00	6385.26
300,000 to 400,000 DKK	136	12750.00	7235.29	8150.74
400,000 to 500,000 DKK	84	11160.71	6535.71	8982.14
500,000 to 1,000,000 DKK	48	13125.00	9437.50	10656.25
1,000,000 to 1,500,000 DKK	8	18750.00	9187.50	13312.50
All incomes	*1283*	*8392.05*	*5698.36*	*6341.39*

Respondents were also asked whether they typically buy new or used products, and whether they typically buy cheap or expensive products. From Tables 9.2 and 9.3 it is apparent that respondents who typically buy new and/or expensive products have higher average expenditures for both personal products and home products. This is not surprising, of course.

It should in this regard be noted that used products have considerably lower impacts (per consumer) than new products. On the other hand, consumers that mainly buy expensive products get a lesser amount of products for the money spent than consumers who mainly buy cheap products. Since the production of cheap and expensive products has approximately the same impact on the environment, consumers who buy expensive products thus exert a lower environmental impact per Danish krone (DKK) spent.

Table S9.2. Distribution of respondents who mainly buy used and/or new products.

Used or new products?	Respondents	Personal products (DKK)	Home products (DKK)
Only used products (100%)	80	5775.00	3281.25
Mostly used products (75%)	147	6336.73	4000.00
Used/new products (50/50)	472	7630.30	5631.36
Mostly new products (75%)	314	10050.96	6792.99
Only new products (100%)	270	9688.88	6183.33
All respondents	1283	8392.05	5698.36

Table S9.3. Distribution of respondents who mainly buy cheap and/or expensive products.

Cheap or expensive products?	Respondents	Personal products (DKK)	Home products (DKK)
Only cheap products (100%)	169	6097.63	3674.56
Mostly cheap products (75%)	297	6217.17	5035.35
Cheap/expensive products (50/50)	649	8912.17	5916.80
Mostly expensive products (75%)	151	12596.03	8254.97
Only expensive products (100%)	17	12000.00	6352.94
All respondents	1283	8392.05	5698.36

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Personal-Metabolism (PM) coupled with Life Cycle Assessment (LCA) Model: Danish Case Study

Supplementary Information III

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Table S1: List of LCI processes used for assessing environmental impact of urban residents (for accommodation, thermal energy, electricity, road transportation and air travel Ecoinvent 2.2 database was used whereas for food consumption component Ecoinvent 3.1 database was used)

Consumption Component		**Ecoinvent Process**
Accommodation	Custom Model for Standard Danish House	CH: glass wool mat, at plant
		CH: gravel, unspecified, at mine
		CH: gypsum plaster board, at plant
		RER: brick, at plant
		RER: door, inner, wood, at plant
		RER: door, outer, wood-glass, at plant
		RER: fleece, polyethylene, at plant
		RER: polystyrene, general purpose, GPPS, at plant
		RER: reinforcing steel, at plant
		RER: roof tile, at plant
		RER: sawn timber, hardwood, raw, plant-debarked, u=70%, at plant

Consumption Component		Ecoinvent Process
		RER: steel, low-alloyed, at plant
		RER: window frame, aluminium, U=1.6 W/m2K, at plant
		RER: window frame, wood, U=1.5 W/m2K, at plant
		CH: clay plaster, at plant
		CH: concrete, normal, at plant
		CH: disposal, ventilation equipment, decentralized, 180-250 m3/h
		CH: pump 40W, at plant
Heat		CH: heat, at local distribution cogen 160kWe Jakobsberg, allocation energy
Electricity		DK: electricity, production mix DK
Road Transport	Diesel Car	CH: transport, passenger car, diesel, EURO3
		CH: transport, passenger car, diesel, EURO4
		CH: transport, passenger car, diesel, EURO5
	Petrol Car	CH: transport, passenger car, petrol, EURO3
		CH: transport, passenger car, petrol, EURO4
		CH: transport, passenger car, petrol, EURO5
	Electric Car	CH: transport, passenger car, electric, LiMn2O4, city car
	Public Bus	CH: transport, regular bus
	Public Train	CH: transport, average train, SBB mix
	Scooter	CH: transport, scooter
Air Travel		RER: transport, aircraft, passenger
Food	Beef	Red meat, live weight {GLO}| market for | Alloc Def, S
	Pork	Red meat, live weight {GLO}| market for | Alloc Def, S
	Chicken	Chicken for slaughtering, live weight {GLO}| market for | Alloc Def, S

Consumption Component		Ecoinvent Process
	Milk	Cow milk {GLO}| market for | Alloc Def, S
	Cheese	Cheese, from cow milk, fresh, unripened {GLO}| market for | Alloc Def, S
	Potato	Potato {GLO}| market for | Alloc Def, S
	Butter	Butter, from cow milk {GLO}| market for | Alloc Def, S
	Sugar	Sugar, from sugar beet {GLO}| market for | Alloc Def, S
	Bread (Custom Process)	Wheat grain {GLO}| market for | Alloc Def, S
		Tap water {Europe without Switzerland}| market for | Alloc Def, S
		Electricity, medium voltage {DK}| market for | Alloc Def, S
	Vegetables (Custom Process)	Cabbage white {GLO}| market for | Alloc Def, S
		Cauliflower {GLO}| market for | Alloc Def, S
		Carrot {GLO}| market for | Alloc Def, S
		Cucumber {GLO}| market for | Alloc Def, S
		Fava bean, Swiss integrated production {GLO}| market for | Alloc Def, S
		Lettuce {GLO}| market for | Alloc Def, S
		Onion {GLO}| market for | Alloc Def, S
		Potato {GLO}| market for | Alloc Def, S
		Tomato {GLO}| market for | Alloc Def, S
	Fruit (Custom Process)	Apple {GLO}| market for | Alloc Def, S
		Banana {GLO}| market for | Alloc Def, S
		Citrus {GLO}| market for | Alloc Def, S
		Coconut, husked {GLO}| market for | Alloc Def, S
		Grape {GLO}| market for | Alloc Def, S
		Melon {GLO}| market for | Alloc Def, S
		Papaya {GLO}| market for | Alloc Def, S
		Pear {GLO}| market for | Alloc Def, S
		Pineapple {GLO}| market for | Alloc Def, S
		Strawberry {GLO}| market for | Alloc Def, S

Table S2 : Results of 18 midpoints for total consumption of 1281 respondents with detailed statistical parameters

Parameter	ALO	CC	FRD	FET	FE	HT	IR	MET	MEP	MRD	NLT	OD	PMF	POF	TA	TET	ULO	WPD
	m2a	kg CO2 eq	kg oil eq	kg 1,4-DB eq	kg P eq	kg 1,4-DB eq	kg U235 eq	kg 1,4-DB eq	kg N eq	kg Fe eq	m2	kg CFC-11 eq	kg PM10 eq	kg NMVOC	kg SO2 eq	kg 1,4-DB eq	m2a	m^3
Median	1649	6455	1888	57.2	1.80	1104	194658	52.1	6.5	271.4	2.3	6.77E-04	7.46	17.1	25.0	10.3	80.5	10795
Mean	1689	6841	2029	59.3	1.86	1130	222302	53.7	6.7	287.1	2.4	7.30E-04	7.82	18.6	26.0	11.0	94.7	11699
Geometric mean	1562	6058	1764	52.7	1.67	1027	181318	47.9	6.2	253.0	2.3	6.24E-04	7.10	16.4	23.5	10.8	75.3	10242
Q_1 (25^{th} Percentile)	1206	4432	1241	40.1	1.28	765	107552	36.7	4.9	174.0	1.8	4.36E-04	5.36	11.9	18.4	9.3	41.3	6974
Q_3 (75^{th} Percentile)	2027	8705	2595	74.0	2.32	1441	303165	66.8	7.9	374.2	3.0	9.55E-04	9.82	23.5	32.6	12.9	135.9	15380
Min	497	1073	287	13.0	0.41	261	22835	11.7	2.5	45.5	0.8	8.52E-05	1.55	3.0	4.8	7.8	13.1	1935
Max	4523	30265	9715	189.5	6.02	3640	950462	168.3	21.3	1055.4	9.6	0.0038	31.20	112.1	94.9	19.1	370.3	52439

(ALO - Agricultural Land Occupation; CC - Climate Change; FRD - Fossil Depletion; FET - Freshwater Ecotoxicity ; FE - Freshwater Eutrophication; HT - Human Toxicity; IR - Ionizing Radiation; MET - Marine Ecotoxicity; MEP - Marine Eutrophication; MRD - Metal Depletion; NLT - Natural Land Transformation; OD - Ozone Depletion; PMF - Particulate Matter Formation; POF - Photochemical Oxidant Formation; TA- Terrestrial Acidification; TET - Terrestrial Ecotoxicity; ULO - Urban Land Occupation; WPD - Water Depletion)